# EXHIBIT 3

# A Standard Default Color Space for the Internet - sRGB

Michael Stokes (Hewlett-Packard), Matthew Anderson (Microsoft),

Srinivasan Chandrasekar (Microsoft), Ricardo Motta (Hewlett-Packard)

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## Introduction

Hewlett-Packard and Microsoft propose the addition of support for a standard color space, sRGB, within the Microsoft operating systems, HP products, the Internet, and all other interested vendors. The aim of this color space is to complement the current color management strategies by enabling a third method of handling color in the operating systems, device drivers and the Internet that utilizes a simple and robust device independent color definition. This will provide good quality and backward compatibility with minimum transmission and system overhead. Based on a calibrated colorimetric RGB color space well suited to Cathode Ray Tube (CRT) monitors, television, scanners, digital cameras, and printing systems, such a space can be supported with minimum cost to software and hardware vendors. Our intent here is to promote its adoption by showing the benefits of supporting a standard color space, and the suitability of the standard color space, sRGB, we are proposing. We will describe some of the system issues and propose a methodology for to implement support for sRGB and color management on the World Wide Web.

# Part 1 : History and Background of sRGB color space

## A Perceived Need

Recently the International Color Consortium has proposed breakthrough solutions to problems in communicating color in open systems. Yet the ICC profile format does not provide a complete solution for all situations.

Currently, the ICC has one means of tracking and ensuring that a color is correctly mapped from the input to the output color space. This is done by attaching a profile for the input color space to the image in question. This is appropriate for high end users. However, there are a broad range of users that do not require this level of flexibility and control. Additionally, most existing file formats do not, and may never support color profile embedding, and finally, there are a broad range of uses actually discourage people from appending any extra data to their files. A common standard RGB color space addresses these issues and is useful and necessary.

We expect application developers and users that do not want the overhead of embedding profiles with documents or images to convert them to a common color space and store them in that format. Currently there is a plethora of RGB monitor color spaces attempting to fill this void with little guidance or attempts at standards. There is a need to merge the many standard and non-standard RGB monitor spaces into a single standard RGB color space. Such a standard could dramatically improve the color fidelity in the desktop environment. For example, if operating system vendors provide support for a standard RGB color space, the input and output device vendors that support this standard color space could easily and confidently communicate color without further color management overhead in the most

common situations. The three major factors of this RGB space are the colorimetric RGB definition, the equivalent gamma value of 2.2 and the well-defined viewing conditions, along with a number of secondary details necessary to enable the clear and unambiguous communication of color.

# Colorimetric RGB

The dichotomy between the device dependent (e.g. amounts of ink expressed in CMYK or digitized video voltages expressed in RGB) and device independent color spaces (such as CIELAB or CIEXYZ) has created a performance burden on applications that have attempted to avoid device color spaces. This is primarily due to the complexity of the color transforms they need to perform to return the colors to device dependent color spaces. This situation is worsened by a reliability gap between the complexity and variety of the transforms, making it hard to ensure that the system is properly configured.

To address these concerns and serve the needs of PC and Web based color imaging systems, we propose a colorimetric RGB specification that is based on the average performance of personal computer displays. This solution is supported by the following observations:

- Most computer monitors are similar in their key color characteristics - the phosphor chromaticities (primaries) and transfer function
- RGB spaces are native to displays, scanners and digital cameras, which are the devices with the highest performance constraints
- RGB spaces can be made device independent in a straightforward way. They can also describe color gamuts that are large enough for all but a small number of applications.

This combination of factors makes a colorimetric RGB space well suited for wide adoption since it can both describe the colors in an unambiguous way and be the native space for actual hardware devices. This, many readers will recognize, describes in a roundabout way what has been the practice in color television for some 45 years. This proven methodology provides excellent performance where it is needed the most, the fast display of images in CRT monitors.

# Gamma and the desired CRT gamma of 2.2

For computer software and hardware designers the most significant aspect of the proposed space is the 2.2 CRT gamma. Because gamma correction tends to be a topic surrounded by confusion, it is worthwhile spending a few paragraphs discussing it.

## Definitions of gamma

We start this discussion by defining four separate aspects of gamma.

1. *viewing gamma* - the overall system gamma that we want to obtain and is typically computed by multiplying the camera gamma by the display gamma as shown below.

$$viewing\ gamma = camera\ gamma \times display\ gamma \tag{0.1}$$

2. *camera gamma* - the characteristic of the image sensor or video camera standard transfer function
3. *CRT gamma* - the gamma of the physical CRT.
4. *LUT gamma* - the gamma of the frame buffer lookup table
5. *display gamma* - the "display system" gamma downstream of the frame buffer which is typically computed by multiplying the CRT gamma by the LUT gamma as shown below.

$$display\ gamma = CRT\ gamma \times LUT\ gamma \quad (0.2$$

These definitions have been kindly provided by the World Wide Web Consortium and are included in the PNG file format specification available at http://www.w3.org/pub/WWW/TR/REC-png-multi.html. These definitions do *not* describe the individual gamma parameter in equation 0.4 below. Instead, they describe the resulting power parameter of the appropriate transfer function when fit by a power function. It is extremely important to keep this distinction clear or else one implicitly assumes equations 0.4 and 0.5 are equivalent and the system black level is truly 0.0 and the system gain is 1.0.

## Viewing Gamma

The reason that a viewing gamma of 1.125 is used instead of 1.0 is to compensate for the viewing environment conditions, including ambient illumination and flare. Historically, viewing gammas of 1.5 have been used for viewing projected slides in a dark room and viewing gammas of 1.25 have been used for viewing monitors in a very dim room. This very dim room value of 1.25 has been used extensively in television systems and assumes a ambient luminance level of approximately 15 lux. The current proposal assumes an encoding ambient luminance level of 64 lux which is more representative of a dim room in viewing computer generated imagery. Such a system assumes a viewing gamma of 1.125 and is thus consistent with the 709 standard described below. While we believe that the typical office or home viewing environment actually has an ambient luminance level around 200 lux, we found it impractical to attempt to account for the resulting large levels of flare that resulted. In addition, recent work by the ISO JTAG2 standards committee supports the ambient luminance level of 64 lux.

If the viewing condition is different from the standard, then the decoding process must compensate. This can be done by modifying the gamma values in equation 1.2 below by the appropriate factor. If one does modify the gamma values in equation 1.2 below, extreme care must be taken to avoid quantization errors when working with 24 bit images and high viewing flare levels.

The ITU-R BT.709 transfer function in combination with its target monitor is attempting to achieve a viewing gamma of 1.125 by incorrectly assuming a CRT gamma of 2.5 and an LUT gamma of 1.0/2.222 as shown in the equation below. The justification of a viewing gamma value of 1.125 is described below in the section on viewing environment compensation.

$$1.125 = {}^{2.5}\!/_{2.\bar{2}} = {}^{2.2}\!/_{1.956} \qquad (0.3)$$

Using the actual power function fit value for the 709 transfer function of 1.0/1.956 and maintaining the display gamma of 1.125, we can solve for the ideal target monitor gamma of 2.2. This is consistent with the CRT gamma value proposed in this paper.

## Camera Gamma

The camera gamma 1.0/2.2 was the standard for television camera encoding before the advent of color TVs and was formalized in 1953 with the NTSC broadcast television standards. More recently ITU-R BT.709 has been adopted internationally and contains camera gamma of 1.0/1.956. The actual exponent factor in the 709 transfer function is 1.0/2.222. Despite the fact that the exponent of the 709 function is 1.0/2.222, the actual 709 encoding transfer function is closer to a CRT gamma of 1.0/1.956 than 1.0/2.222. This is due to the large offset of 0.099 in the transfer function equation. This is well matched to the eye's own non-linearity and it helps minimize transmission noise in the dark areas.

Broadcast television camera gamma standards and the ITU-R BT.709 standard in particular defines the transformation of real world CIEXYZ tristimulus values into a target RGB monitor space. This is

essentially a composite of two transformations; one from real world CIEXYZ tristimulus values into standard monitor CIEXYZ tristimulus values and one from these standard monitor CIEXYZ tristimulus values into standard monitor rgb values. The resulting image is not an exact appearance match of the original scene, but instead is a preferred reproduction of the original scene that is consistent with the limitations of a monitor.

Because all television sets have to display content generated with this encoding, it was very important for all CRT gamma designs to conform to it. Only recently has the computer monitor market become as large as the TV market. As a result, most computer monitors still perform optimally with imagery using with a camera gamma value of approximately 1.0/1.956

## CRT Gamma

The non-linearity of the electro-optical radiation transfer function of CRTs is often expressed by a mathematical power function exponent parameter called gamma. This transfer function describes how much visible radiant energy (cd/m$^2$) results from voltages applied to the CRT electron-gun. Because most of the other characteristics of CRT based computer monitors are linear (including DACs and video amplifiers) the resulting transfer function has the same gamma value determining its non-linearity.

$$I = A(k_1 D + k_2)^{gamma} \qquad (0.4)$$

Where $k_1$ and $k_2$ are the system gain and offset, D is the normalized pixel value, A is the maximum luminance of the CRT and I is the resulting luminance. This equation and a thorough analysis of the CRT characteristics and history are well described in "An Analytical Model for the Colorimetric Characterization of Color CRTs" by Ricardo Motta, Rochester Institute of Technology, 1991.

The key point that we wish to convey here is that gamma component of the CRT gamma is dependent only on the electron gun design, and the vast majority of monitors and TV sets in use today are based on designs that result, on average, in the value 2.2 for gamma component of the CRT gamma and a 2.2 overall CRT gamma value when typical system gain and offsets are optimally set. Most of the variation between computer monitors and between TV sets are due to the differences in system gain and offsets ($k_1$ and $k_2$), which are partially under control of the user in the form of contrast and brightness knobs. Unfortunately, the actual set-up is often not known, but the best CRT performance happens when the system offset puts the dark parts of the images at the CRT cut-off, i.e. the black (pixel value 0) parts of the CRT image are just about to emit light. Under these conditions equation 0.4 above becomes

$$I = AD^{gamma} \qquad >(0.5)$$

and the monitor has the widest-dynamic range. Unfortunately, this is not the common condition. Unfortunately the simplified form in equation 0.5 is what is usually found in the computer literature.

There are significant variations, with widest variations being in the set-up and screen reflectivity (older and less expensive display can reflect up to 20% of the ambient light). These factors typically can not be characterized a priori since they might change in the course of the day (ambient light) and at the whim of the user (by modifying contrast and brightness). Yet, in practice, the process tends to be self-regulatory, with users looking for darker places to set their monitors and modifying the controls to re-establish the expected display appearance. Exhaustive testing carried on at Hewlett-Packard on VGA computer monitors from many brands has shown the average CRT gamma to be indeed 2.2, with a standard deviation of about 0.2.

## LUT gamma

Two special circumstances will lead computer systems to systematically deviate from the 2.2 CRT gamma and the 1.0 LUT gamma that we propose - color dithering for 16 color systems and system imposed gamma correction via look-up-tables (LUT).

The first of course was very common until a few years ago. Until about 1993 most Windows PCs were well described by a display gamma of 1.8 because despite having 2.2 CRT gamma systems, the colors were dithered into the 4 bit frame buffers, resulting in a flattening of the system transfer function. This happens because screen dithering mixes colors linearly in the eye, making it less dependent on the CRT non-linearity. Since currently most Windows PC support 16 or 24 bit color modes, 2.2 CRT gamma is now the average.

The second systematic deviation happens when the graphics system in the computer hardware or software imposes its own gamma correction. This is done for a variety of reasons, but is usually an attempt to compromise between image display and graphics/image processing performance (most computer graphic rendering assumes linear radiation space, e.g. transparency operations, and so does image processing, e.g. scaling and filtering). The gamma correcting of image data can be described by applying an exponent to the image data. For the Macintosh the display gamma is around 1.571 using a LUT gamma of 1.4 (2.2/1.4 = 1.571) and for SGI workstations the display gamma is around 1.294 using a LUT gamma of 1.7 (2.2/1.7 = 1.294).

There has been significant confusion derived from assuming the CRT gamma value is identical to the exponent in equation 0.4. This has led to many claims of CRT gamma values of 2.5 for video, 1.8 for the Apple Macintosh and 1.4 for SGI monitors. Unfortunately, it has been our experience that this misconception is not well founded in the actual physics of the displays and solid measurements.

# sRGB and ITU-R BT.709 Compatibility

There has been some confusion in previous versions of this proposal with respect to compatibility with the ITU-R BT.709 standard. Many readers have also expressed concern for compatibility with the 709 recommendation in general. After review, the authors have confirmed the compatibility between this proposal and the 709 recommendation. Unfortunately, the ITU-R BT.709 standard can be somewhat confusing for many readers. Below is an attempt to clarify and reduce this confusion.

For a single color space to achieve acceptance, it must be objective, that is, have a tightly-defined relationship with the CIE standards. We are fortunate to have obtained in April 1990 unanimous worldwide agreement on a calibrated nonlinear RGB space for HDTV production and program exchange: Rec. ITU-R BT.709. This recommendation specifies the encoding of real world scene tristimulus values into a standard monitor RGB color space assuming a dark viewing condition. HP and Microsoft suggest using these parameters as the basis for the sRGB color space but with a dim viewing condition which is closer to most typical viewing environments for computer displayed imagery. Unfortunately the ITU specification is rather vague on defining the target monitor. This paper attempts to provide a clear and well defined target monitor for the Rec. ITU-R BT.709 camera encoding standard for a dim viewing environment.

The ITU-R BT.709 standard specifically describes the encoding transfer function for a video camera that when viewed on a "standard" monitor will produce excellent image quality. The implicit target of this encoding is a standard video monitor whose transfer function or CRT gamma is *not* explicitly delineated. Instead a typical monitor setup is assumed. This paper attempts to explicitly describe a standard monitor setup that is compatible with the 709-encoding standard.

This is illustrated in Figures 1-3 below. Figure one is directly derived from the ITU-R BT.709 standard. This standard provides mathematical methods to transform from tristimulus values of the scene using a video camera into a reference monitor device space.

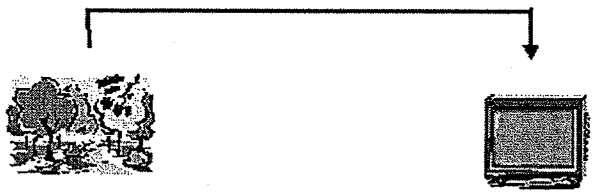



Figure 1

Figure two expands the implicit step of these methods and shows the transformation between the original scene tristimulus values into the target monitor tristimulus values. Since these two viewing conditions are different, an implicit compensation is made to account for these differences (i.e. flare and ambient luminance). In order to provide an independent monitor reference color space, the monitor compensation methods must be extracted from this confounded compensation. This is precisely the goal of the sRGB color space.

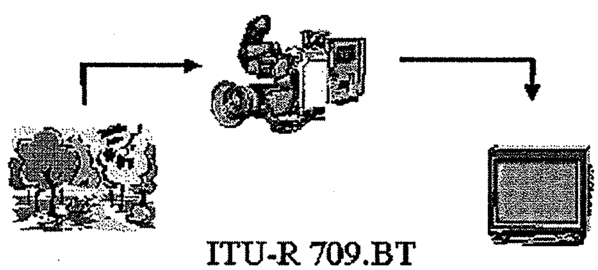



Figure 2

Figure three illustrates both the sRGB color space and the extraction of the monitor only specifications implicit within the ITU-R BT.709 standard. By producing such a monitor space, one can then transfer the ITU-R BT.709 encoded signals to other devices. By building on this system, the sRGB color space provides a monitor definition that can be used independently from the ITU-R BT.709 standard while maintain compatibility. This allows for the well-defined transfer of color information across the World Wide Web as described in the other section of this paper.

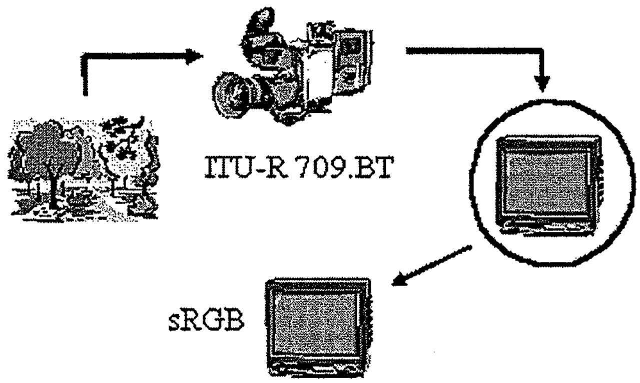



Figure 3

This sRGB recommendation essentially defines the second part of this transformation between the target RGB monitor space and the monitor CIEXYZ tristimulus values in a dim viewing environment. This is required to maintain a consistent monitor centric color reproduction process that is typical of the web and is consistent with recommendations of the International Color Consortium. This is also consistent with maintaining the preferred reproduction encoding of the ITU standard.

In summary, there has been some concern with the choice of a 2.2 CRT gamma with a 1.0 LUT gamma as opposed to a 1.571 (2.2/1.4) or a 1.294 (2.2/1.7) display gamma. We feel that there are many reasons to support a 2.2 CRT, including;

- compatibility with a large legacy of images
- Photo CD,
- many Unix workstations,
- PC's with 256+ colors and their desktop color schemes and icons,
- several ultra-large image collections,
- analog television,
- Apple Macintosh video imagery,
- CCIR 601 images,
- a better fit with Weber's fraction,
- compatibility with numerous standards,
- TIFF/EP,
- EXIF,
- digital TV,
- HDTV,
- analog video,
- PhotoCD,
- it is closer to native CRTs gamma,
- and consistency with a larger market of displays.

# Alpha Channel Masking and Computer Graphics Compatibility

Another concern that has been expressed about encoding using a gamma of 2.2 is the use of alpha masking. Typically computer graphics effects, including alpha masking, operate in an optical intensity environment as opposed to a visually uniform one. This mandates using a linear gamma of 1.0 in most computer graphic operations which is obviously incompatible with the visually uniform encoding using

a gamma of 2.2. In a 24 bit encoding scheme, encoding a mid-level gray using a gamma of 1.0 would result in a digital count of 46. Such an encoding scheme would create visually objectionable artifacts such as contours. Therefore we recommend that effects such as alpha masking be performed either prior to encoding or by decoding to a color resolution greater than 24 bits and then converting into linear intensity space.

Again, it is fundamental to realize that there are two common operational spaces discussed here; 1) the linear intensity space in which most optical and synthetic visualization operations work within and 2) a nearly visually perceptibly uniform space in which visual based operations, compression and many devices work within. This difference is vitally important to remember since both types of operations are required and thus interaction between these two types of spaces occur frequently.

# Part 2: Definition of the sRGB Color Space

## A Single RGB Standard Color Space

There are two parts to the proposed standard described in this paper; the viewing environment parameters with its dependencies on the human visual system and the standard device space colorimetric definitions and transformations. The viewing environment descriptions contain all the necessary information, when combined with most color appearance models, to provide conversions between the standard and target viewing environments. The colorimetric definitions provide the transforms necessary to convert between the sRGB color space and the CIEXYZ two degree observer color space.

## sRGB reference viewing environment

Reference viewing environments are defined for standard RGB in Table 0.1.

**TABLE 0.1 sRGB viewing environment Parameters**

| **Condition** | **sRGB** |
|---|---|
| Luminance level | 80 cd/m$^2$ |
| Illuminant White | $x = 0.3127, y = 0.3291$ (D65) |
| Image surround | 20% reflectance |
| Encoding Ambient Illuminance Level | 64 lux |
| Encoding Ambient White Point | x = 0.3457, y = 0.3585 (D50) |
| Encoding Viewing Flare | 1.0% |
| Typical Ambient Illuminance Level | 200 lux |
| Typical Ambient White Point | $x = 0.3457, y = 0.3585$ (D50) |
| Typical Viewing Flare | 5.0% |

The sRGB reference viewing environment corresponds to conditions typical of monitor display viewing conditions.

The *luminance level* is representative of typical CRT display levels.

The chromaticities of the *illuminant white* are those of CIE $D_{65}$.

The *image surround* is defined as "20%" of the maximum white luminance. This is close to a CIELAB

L* value of 50, while maintaining computational simplicity. The areas surrounding the image being viewed are similar in luminance and chrominance to the image itself. This surround condition would correspond, for example, to a reflection print displayed on a spectrally non-selective gray background of about twenty percent reflectance, where the print and the background are uniformly illuminated by the same light source.

This specification defines the concepts of an encoding viewing environment and a typical viewing environment. The encoding viewing environment is consistent with recent discussions within the ISO JTAG2 committee for graphic arts and photographic viewing conditions for photographic images on monitors. If possible to achieve, this is the recommended viewing environment for viewing photographic images on monitors. The typical viewing environment is representative of a typical office or home office viewing environment for personal computers.

For optimal results, we recommend using the encoding viewing environment when viewing sRGB encoded images. We also recognize that this is quite different from typical viewing environment.

While one would theoretically use the viewing conditions which represent the actual or typical viewing environment, if this is done with 24 bit images a significant loss in the quality of shadow detail results. This is due to encoding the typical viewing flare of approximately 5.0 percent into a 24 bit image as opposed to the encoding viewing flare of 1 percent. Therefore we recommend using the encoding viewing environment for most situations including when one's viewing environment is consistent with the typical viewing environment and not the encoding viewing environment.

The *encoding ambient illuminance level* is intended to be representative of a dim viewing environment. Note that the illuminance is at least an order of magnitude lower than average outdoor levels and approximately one-third of the typical ambient illuminance level.

The chromaticities of the *encoding ambient white* are those of CIE $D_{50}$.

*Encoding viewing flare* is specified to be 1.0% of the maximum white-luminance level.

The *typical ambient illuminance level* is intended to be representative of a typical office viewing environment. Note that the illuminance is at least an order of magnitude lower than average outdoor levels.

The chromaticities of the *typical ambient white* are those of CIE $D_{50}$.

*Typical Viewing flare* is specified to be 5.0% of the maximum white-luminance level.

# Colorimetric definitions and digital encodings

sRGB in combination with the reference viewing environments can be defined from standard CIE colorimetric values through simple mathematical transformations.

CIE colorimetry provides the basis for sRGB encoding of the color. For the calculation of CIE colorimetric values, it is necessary to specify a viewing environment and a set of spectral sensitivities for a specific capture device. The definitions for RGB given in equations 1.1 to 1.3 are based on the colorspace's respective viewing environment.

The CIE chromaticities for the red, green, and blueITU-R BT.709 reference primaries, and for CIE Standard Illuminant $D_{65}$, are given in Table 0.2.

**TABLE 0.2 CIE chromaticities for ITU-R BT.709 reference primaries and CIE standard illuminant**

| | Red | Green | Blue | D65 |
|---|---|---|---|---|
| *x* | 0.6400 | 0.3000 | 0.1500 | 0.3127 |
| *y* | 0.3300 | 0.6000 | 0.0600 | 0.3290 |
| *z* | 0.0300 | 0.1000 | 0.7900 | 0.3583 |

sRGB tristimulus values for the illuminated objects of the scene are simply linear combinations of the 1931 CIE XYZ values and these *RGB* tristimulus values can be computed using the following derived relationship:

$$\begin{bmatrix} R_{sRGB} \\ G_{sRGB} \\ B_{sRGB} \end{bmatrix} = \begin{bmatrix} 3.2410 & -1.5374 & -0.4986 \\ -0.9692 & 1.8760 & 0.0416 \\ 0.0556 & -0.2040 & 1.0570 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \tag{1.1}$$

In the RGB encoding process, negative sRGB tristimulus values, and sRGB tristimulus values greater than 1.00 are not typically retained. When encoding software cannot support this extended range, the luminance dynamic range and color gamut of RGB is limited to the tristimulus values between 0.0 and 1.0 by simple clipping. This gamut, however, is large enough to encompass most colors that can be displayed on CRT monitors.

The sRGB tristimulus values are next transformed to nonlinear sR'G'B' values as follows:

If $R_{sRGB}, G_{sRGB}, B_{sRGB} \leq 0.00304$

$$\begin{aligned} R'_{sRGB} &= 12.92 \times R_{sRGB} \\ G'_{sRGB} &= 12.92 \times G_{sRGB} \\ B'_{sRGB} &= 12.92 \times B_{sRGB} \end{aligned} \tag{1.2a}$$

else if $R_{sRGB}, G_{sRGB}, B_{sRGB} > 0.00304$

$$\begin{aligned} R'_{sRGB} &= 1.055 \times R_{sRGB}^{(1.0/2.4)} - 0.055 \\ G'_{sRGB} &= 1.055 \times G_{sRGB}^{(1.0/2.4)} - 0.055 \\ B'_{sRGB} &= 1.055 \times B_{sRGB}^{(1.0/2.4)} - 0.055 \end{aligned} \tag{1.2b}$$

The effect of the above equations is to closely fit a straightforward gamma 2.2 curve with an slight offset to allow for invertability in integer math. Therefore, we are maintaining consistency with the gamma 2.2 legacy images and the video industry as described previously.

Finally, the nonlinear sR'G'B' values are converted to digital code values. This conversion scales the above sR'G'B' values by using the equation below where WDC represents the white digital count and KDC represents the black digital count.

$$\begin{aligned} R_{8bit} &= \left((WDC - KDC) \times R'_{sRGB}\right) + KDC \\ G_{8bit} &= \left((WDC - KDC) \times G'_{sRGB}\right) + KDC \\ B_{8bit} &= \left((WDC - KDC) \times B'_{sRGB}\right) + KDC \end{aligned} \tag{1.3}$$

This current specification proposes using a black digital count of 0 and a white digital count of 255 for 24-bit (8-bits/channel) encoding. The resulting RGB values are formed according to the following equations:

$$R_{8bit} = \left((255.0 - 0.0) \times R'_{sRGB}\right) + 0.0$$
$$G_{8bit} = \left((255.0 - 0.0) \times G'_{sRGB}\right) + 0.0$$
$$B_{8bit} = \left((255.0 - 0.0) \times B'_{sRGB}\right) + 0.0 \qquad (1.4)$$

This obviously can be simplified as shown below.

$$R_{8bit} = 255.0 \times R'_{sRGB}$$
$$G_{8bit} = 255.0 \times G'_{sRGB}$$
$$B_{8bit} = 255.0 \times B'_{sRGB} \qquad (1.5)$$

The reverse relationship is defined as follows;

$$R'_{sRGB} = R_{8bit} \div 255.0$$
$$G'_{sRGB} = G_{8bit} \div 255.0$$
$$B'_{sRGB} = B_{8bit} \div 255.0 \qquad (1.6)$$

If $R_{sRGB}, G_{sRGB}, B_{sRGB} \leq 0.03928$

$$R_{sRGB} = R'_{sRGB} \div 12.92$$
$$G_{sRGB} = G'_{sRGB} \div 12.92$$
$$B_{sRGB} = B'_{sRGB} \div 12.92 \qquad (1.7a)$$

else if $R_{sRGB}, G_{sRGB}, B_{sRGB} > 0.03928$

$$R_{sRGB} = \left[\left(R'_{sRGB} + 0.055\right) / 1.055\right]^{2.4}$$
$$G_{sRGB} = \left[\left(R'_{sRGB} + 0.055\right) / 1.055\right]^{2.4}$$
$$B_{sRGB} = \left[\left(R'_{sRGB} + 0.055\right) / 1.055\right]^{2.4} \qquad (1.7b)$$

and

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.4124 & 0.3576 & 0.1805 \\ 0.2126 & 0.7152 & 0.0722 \\ 0.0193 & 0.1192 & 0.9505 \end{bmatrix} \begin{bmatrix} R_{sRGB} \\ G_{sRGB} \\ B_{sRGB} \end{bmatrix} \qquad (1.8)$$

Digital broadcast television uses a black digital count of 16 and a white digital count of 235 in order to provide a larger encoded color gamut. We do not propose using this encoding at this time, due to the large legacy of images and applications using the previous black and white digital coding counts. However, it is vital to allow for a future revision to provide this capability.

# Part 3 : Implementation on the Web

## Color Spaces

***Definition:***

*A color space is a model for representing color numerically in terms of three or more coordinates. e.g. The RGB color space represents colors in terms of the Red, Green and Blue coordinates.*

For color to be reproduced in a predictable manner across different devices and materials, it has to be described in a way that is independent of the specific behavior of the mechanisms and materials used to produce it. For instance, color CRTs and color printers use very different mechanisms for producing color. To address this issue, current methods require that color be described using device independent color coordinates, which are translated into device dependent color coordinates for each device.

## Color Management

***Definition:***

*Color management is a term that describes a technology that translates the colors of an object (images, graphics or text) from their current color space to the color space of the output devices like monitors, printers, ...*

Traditionally, operating systems have supported color by declaring support for a particular color space, RGB in most cases. However, since RGB varies between devices, color was not reliably reproduced across different devices.

The high-end publishing market could not meet its needs with the traditional means of color support, so the various OS's added support for using International Color Consortium (ICC) profiles to characterize device dependent colors in a device independent way. They use the profiles of the input device that created an image and the output device that displayed the image and create a transform that moves the image from the input device's color space to the output device's color space. This resulted in very accurate color. However, it also involved the overhead of transporting the input device's profile with the image and running the image through the transform.

HP and Microsoft propose an additional means of managing color that is optimized to meet the needs of most users without the overhead of carrying an ICC profile with the image: the addition to the OS and the Internet of support for a Standard Color Space. Since the image is in a known color space and the profile for that color space would ship with the OS and browser, this enables the end users to enjoy the benefits of color management without the overhead of larger files. While it may be argued that profiles could buy slightly higher color accuracy, we believe that the benefits of using a standard color space far out-weigh the drawbacks for a wide range of users. The migration of devices to natively support the standard color space will further enhance the speed and quality of the user experience.

We are proposing the use of the color space, sRGB, that is consistent with but is a more tightly defined derivative of Rec. ITU-R BT.709 as the standard color space for the OS's and the Internet. In April of 1990 this space obtained unanimous worldwide agreement as the calibrated nonlinear RGB space for HDTV production and program exchange.

## Proposed Style Sheet Syntax for specifying sRGB on the

## Internet

We propose that all page elements defined in the style sheets be assumed to be in the sRGB color space unless embedded ICC profiles indicate otherwise.

We further propose a new CSS-1 property, `rendering-intent`, with the following syntax to specify the user rendering intents of page elements. These rendering intent values are defined to be consistent with the International Color Consortium rendering intent values (http://www.color.org) of saturation, perceptual, absolute colorimetric and relative colorimetric.

Syntax

```
Value: saturation | perceptual | absolute  | relative
Initial: perceptual
Applies to: all elements
Inherited: yes
Percentage values: N/A
```

Example:

```
BODY { rendering-intent: saturation }
IMG.perceptualintent { rendering-intent: perceptual }
#mypic001 { rendering-intent: A }
<IMG ID=mypic001 SRC="http://www.site.com/layout.mypic001.png">
<IMG CLASS="perceptualintent" SRC="http://www.site.com/layout.mypic002.gif">
```

## Standard Color Space in Practice

Once page elements are converted to sRGB, the browser needs to interpret the color space correctly and use the OS color management to image the page. The following table summarizes how the browser handles color management in each of the possible scenarios.

| | **Style Sheet Colors (sRGB)** | **HTML Page with no Color Space information** | **Re-purpose Data outside of Browser/ HTML environment** |
|---|---|---|---|
| **Embedded Profile in Image** | Color Space for Image determined by embedded profile. | Color Space for Image determined by embedded profile. | Color Space for Image determined by embedded profile. |
| **Image file specifies sRGB** | Color Space for Image is sRGB | Color Space for Image is sRGB | Color Space for Image is sRGB |
| **Image has no Color space information.** | Color Space for Image is sRGB | Color Space for image is sRGB. | Color Space for image is sRGB. |
| **Text** | Color Space for text is sRGB | Color Space for text is sRGB. | Color Space for text is sRGB. |
| **Graphics** | Color Space for Graphics is sRGB | Color Space for graphics is sRGB. | Color Space for graphics is sRGB. |

## Browsing Scenarios

The following cases describe what an end-user sees in the various scenarios:

1. **Image not in sRGB, does not have an embedded ICC profile, and no monitor/output device**

**ICC profile**

This is the behavior before color management systems were added. Even though the image is assumed to be in sRGB color space, it is imaged (displayed, printed etc.) without translation to the device color space since the output profile is not available. The quality varies tremendously since output device characteristics differ greatly.

2. **Image not in sRGB, does not have an embedded ICC profile, and system has a monitor/output device ICC profile**

   Since the image has no ICC profile, it is assumed to be in the sRGB color space. In this scenario, the resulting image will be consistent across devices; however it could be different from the original image.

3. **Image in sRGB, and no monitor/output device ICC profile**

   In this scenario, the image has been run through a transform that consists of the input device ICC profile, and the sRGB ICC profile, or it was created using devices that conform to sRGB. However, since the system has no ICC profile for the output device, it will simply assume the image is in the device's color space. If all the images rendered on the output device are in sRGB, then they will at least be consistent with respect to each other on a given monitor/output device.

4. **Image in sRGB, and system has a monitor/output device ICC profile**

   In this scenario, the image has been run through a transform that consists of the input device ICC profile, and the sRGB ICC profile, or it was created using devices that conform to sRGB. Because the system has an ICC profile for the output device, the image can be converted to the output device's color space and imaged. The resulting image will be consistent across devices, and will be very close to the original in appearance.

5. **Image in sRGB, and monitor/output device is sRGB compliant**

   In this scenario, the image has been run through a transform that consists of the input device ICC profile, and the sRGB ICC profile, or it was created using devices that conform to sRGB. As the output device has been designed to conform with sRGB, and is associated with that ICC profile, a transform is not necessary for this case. The OS realizes that no transformation is required and simply images the image directly on the output device. This case is ideal since there is no color transformation at output time, and the image is more compact since there is no ICC profile embedded in it. The resulting image will be consistent across devices, and will be very close to the original in appearance.

6. **Image not in sRGB, has an embedded ICC profile, and no monitor/output device ICC profile**

   This would be treated the same as the "Image not in sRGB, does not have an embedded ICC profile, and no monitor/output device ICC profile" scenario.

7. **Image not in sRGB, has an embedded ICC profile, and system has a monitor/output device ICC profile**

   This is the standard color management scenario. The two ICC profiles are combined to produce a transform that will map the colors of the image into the output device's color space. The resulting image will be consistent across devices, and will be very close to the original in appearance.

# Authoring Scenarios

The following scenarios describe how to get an image into the sRGB color space when creating it.

1. **Image created on a device that has no ICC profiles and is not sRGB compliant**

   Display the image on a monitor that is sRGB compliant or that has an ICC profile. Edit the image until it looks good on the monitor. For monitors that are not sRGB compliant but have ICC profiles, depending on the capabilities of the application, either use the application to save the image as sRGB or embed the monitor's profile into the image, and use a tool to create a transform with the monitor's profile and the sRGB profile and run the image through the transform. If the image file format supports it, specify the image is in sRGB.

2. **Image created on a device that has ICC profiles and is not sRGB compliant**

   Use a tool to create a transform with device's profile and the sRGB profile. Then run the image through the transform, specify the image is in sRGB if the image file format supports it.

3. **Image created on a device that is sRGB compliant**

   Specify the image is in sRGB if the image file format supports this.

# Suggestions to benefit from sRGB

1. CRT manufacturers who build monitors in compliance with the sRGB specification will get faster display times for objects in this color space. (No transformation needs to occur.)
2. Scanner and digital camera manufacturers who optimize the color transforms and gamma correction for compatibility with sRGB will benefit for the same reason.

# Palette Issues

There are several different scenarios to consider when dealing with palettized images and displays.

1. **Image does not have a color table (> 8bpp), and client monitor is not palettized**

   The image is run through a color matching transform as described in the previous section, and the resulting 24bpp image is displayed on the monitor.

2. **Image has a color table (8bpp) and client monitor is not palettized**

   The color table accompanying the image is run through a color matching, and the resulting color table is used with the image for display. The displayed image is very close to original image.

3. **Image does not have a color table (>8bpp) and client monitor is palettized.**

   The software displaying the image (eg. browser) should use the default palette that is defined in sRGB space, convert it into device color space by running it through a color matching transform, and use this palette to display the image. The resulting image gets dithered into the closest possible colors on the display. The assumption is that the monitor profile is created with the default palette selected.

4. **Image has a color table (8bpp) and was created using the default palette and client monitor**

**is palettized**

The software displaying the image should follow the same steps as above. The resulting image is very close to the original image and unintentional dithering is eliminated. If the original image only had colors in the default palette, the final image doesn't have any dithering.

5. **Image has a color table (8bpp) and was created using an arbitrary palette and client monitor is palettized**

   If the client monitor only has a palettized profile and can only display the image by discarding this profiled palette and replacing it with an uncalibrated palette, we do *not* recommend to color manage this scenario. If the client monitor is able to treat the image as if it was a truecolor (unpalettized) image, it should proceed as for case 3 above.

Note that cases 3 and 4 assume an industry standard default palette defined in sRGB color space that will be used by authoring and display software to handle 8bpp images. Microsoft and HP are working on the definition of such a palette.

# Conclusion

We believe that the addition of standard color space, sRGB, support to the Internet, device drivers and operating systems is a complementary addition to the existing color management support that utilizes and expands the benefits and availability of color management to a broader range of users. Furthermore, we believe that sRGB overcomes many application developer and end-user reservations to adopting color management. The call for action below presents a clear path forward to improved color management.

# Call for action

1. OS and authoring tools should utilize CRT calibration methods to ensure that images created locally on the monitor are properly translated into sRGB.
2. Authoring tools should enable the use of the OS color management tools to transform the incoming images into sRGB by combining the incoming device ICC profiles with the sRGB ICC profile. These images will be stored in the original file format (like GIF, PNG and JPEG), but with the correct colors.
3. Authoring tools should enable the user to view and edit text and graphics in sRGB.
4. Web page creators should publish content in sRGB.
5. Browser vendors should support the style sheet extensions proposed above and use the OS color management tools to ensure that colors are properly displayed.
6. Organizations that create and support file formats should ensure that the file formats encompass the ability to embed profiles and declare their color space.

# Acknowledgments

The authors would like to sincerely thank Ed Giorgianni of Eastman Kodak Company, Bob Sobol of Hewlett-Packard Company, Charles Poynton, author of A Technical Introduction to Digital Video (John Wiley and Sons), Chris Lilley of W3C, Dave Martindale of the University of British Columbia and many others, for their many insightful comments and encouragement throughout this process.

# EXHIBIT 4

JOURNAL OF THE AUDIO ENGINEERING SOCIETY APRIL 1958, VOLUME 6, NUMBER 2

# A Compatible System of Stereo Transmission by FM Multiplex*

MURRAY G. CROSBY
*Crosby Laboratories, Inc., Hicksville, N. Y.*

A method of applying modulation to the channels of a stereo FM multiplex transmitter is described which provides a "compatible" reception for the monaural listener. By transmitting an additive combination of the microphones on the main channel of the FM transmitter and a subtractive combination on the sub-carrier channel, the main channel transmits a balanced program without the deterioration which would be brought about if the output of only one microphone were transmitted on the main channel. At the receiver the combinations are separated so that the microphones feed the individual loudspeakers directly.

Additional advantages of the system include a 6 db signal-to-noise gain for the sub-carrier channel. This gain is highly desirable because the relatively poor signal-to-noise on the sub-carrier channel curtails the distance range of the stereo transmission. In addition, the signal-to-noise ratio appearing in the receiver channel is made identical so that disturbances due to noise appear symmetrically in both loudspeakers. This results in less annoyance due to noise.

A discussion of relative signal-to-noise ratios on the main channel and sub-carrier channels is given, together with recommendations for optimum performance of a stereo transmission.

## INTRODUCTION

IT IS THE OBJECT of this paper to describe an improved method of transmitting stereophonic sound on an FM transmitter with many advantages for both the monaural and stereo listener. An outstanding advantage is obtained for the monaural listener who is equipped to receive only the main channel without the benefit of stereo reception. With the system to be described, that listener has a compatible reception with the program properly balanced with respect to microphone pickup. The advantages obtained for the stereo listener include a 6-db improvement in signal-to-noise ratio realized from the relatively poor signal-to-noise ratio on the sub-carrier channel, together with a balancing of the signal-to-noise ratios on the two channels so that a more pleasing response is obtained.

## CONVENTIONAL STEREO FM MULTIPLEX SYSTEM

Figure 1 shows the conventional FM multiplexing system which has been used to demonstrate stereophonic transmission by Armstrong and Halstead. In this system microphone *A* is fed to the main channel of the FM transmitter and microphone *B* is fed to the sub-carrier generator which is applied as a multiplex modulation on the FM wave. Application of the sub-carrier modulation may also be accomplished by the use of an auxiliary phase modulator following the main FM modulator with the same basic result in the wave transmitted. This transmitting system is shown in Fig. 2. It utilizes a form of multiple phase modulation,[1] applied to successive stages, so that the resultant modulation is the sum of the separate modulations. Use of this principle for sub-carrier modulation is described by E. H. Armstrong.[2]

The conventional techniques in which the separate microphone outputs are transmitted over the separate channels, as shown in Figs. 1 and 2, have several disadvantages. First of these is the lack of compatibility for the monaural listener. Since that listener will tune in the main channel only, a degraded program pickup is received by virtue of the reception of the output due to one microphone only. That single microphone will receive its pickup from one side of the stage only so that the instruments near it will be over-emphasized and those near the other microphone will be de-emphasized. The pickup of a soloist who happens to be nearest to the opposite microphone will be especially degraded.

The second disadvantage of the conventional system is the unbalance of the signal-to-noise ratios on the main and sub-carrier channels. The sub-carrier channel has an effi-

* Revised manuscript received March 25, 1958. Delivered at the Ninth Annual Convention of the Audio Engineering Society, New York, October 11, 1957.

[1] M. G. Crosby, *U. S. Patent No. 2,104,318*, Jan. 4, 1938.
[2] *U. S. Patent No. 2,630,497*, March 3, 1953.

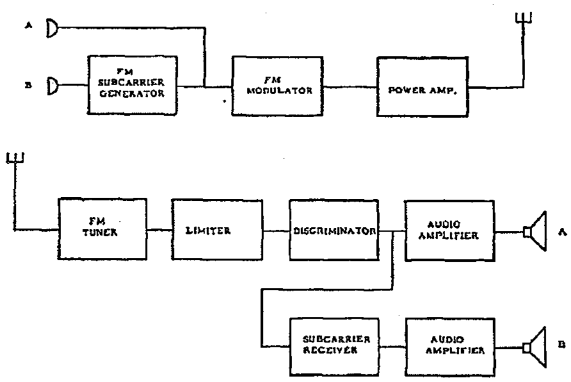



FIG. 1. Conventional FM multiplexing system. Channel A is fed to the main channel while channel B is fed to the sub-carrier generator which is applied as a multiplex modulation on the FM wave. At the receiver, the main channel is derived directly from the discriminator. The sub-carrier channel requires a sub-carrier receiver, with a high-pass filter to remove the main channel, an amplifier, limiter and a detector.

ciency of transmission which is much less than that of the main channel so that the signal-to-noise ratio on one loudspeaker may be as much as 25 db poorer than that on the other. This produces an annoying one-sidedness to noise disturbances which impairs the pleasantness of reception. With the sum-and-difference technique to be described, the signal-to-noise ratios on both loudspeakers are the same and the effective transmission of the sub-carrier channel is improved by 6 db. The 6-db improvement in sub-carrier signal-to-noise ratio is equivalent to a four-to-one increase in power of the transmitter since with the stereo system the performance is only as good as that of the poorest channel. Accordingly the sum-and-difference technique results in an increase in the effective range of the stereo transmission.

This 6-db improvement in signal-to-noise ratio may, under certain conditions, be realized as a 6-db improvement in overall hum and distortion. If it so happens that the hum is predominately from either the sub-carrier channel or the main channel taken alone, the result is a 6-db reduction in hum. This is brought about by the signals from the sum-and-difference combinations adding in phase to produce twice the voltage while the hum remains at a value equal to that of the channel with the highest hum. The only condition in which this improvement would not be realized would be that of an equal hum level in both main and sub-carrier channels which was so phased as to add up to twice the voltage in the sum-and-difference combination. This would be a rare coincidence. In the case of distortion, the same situation exists; the channel with the lowest distortion aids the channel with the highest distortion by a factor of 6 db in the overall system. In experimental work it has been observed that the sub-carrier channel has the least distortion and hum. Under these circumstances the sum-and-difference combination is responsible for a 6-db reduction in both hum and distortion as well as noise, in the overall system response.

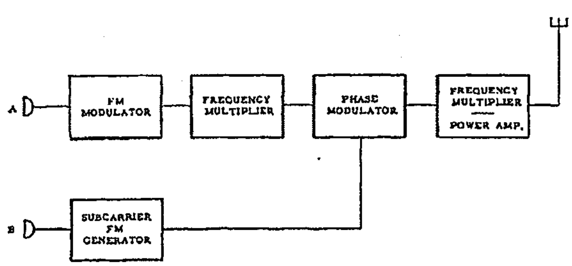



FIG. 2. Another FM multiplex system. This utilizes an auxiliary phase modulator which adds a phase modulation of the sub-carrier to the main channel. The sub-carrier generator is an FM generator with a range between 20 and 75 kc to which is applied the modulation frequency.

## SUM-AND-DIFFERENCE SYSTEM

Figure 3 shows the sum-and-difference technique of applying a twin-channel stereo system to the FM multiplex

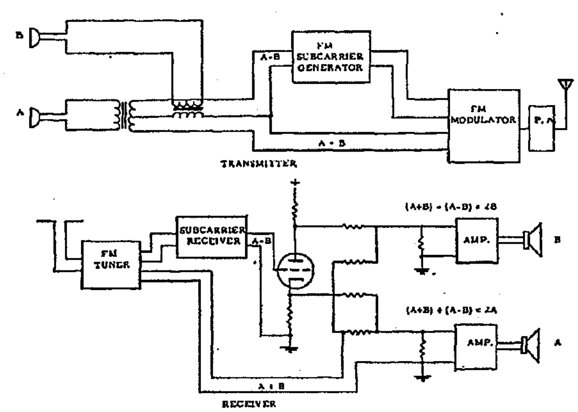



FIG. 3. Sum-and-difference system. Channels A and B are mixed so that the sum $(A+B)$ is fed to the main FM transmitter channel while the difference $(A-B)$ is fed to the sub-carrier generator. Both are modulated in the main FM modulator. At the receiver, $(A+B)$ appears at the output of the receiver discriminator and $(A-B)$ at the output of a sub-carrier receiver. A phase inverter adds and subtracts these two signals and separates the original two channels.

system. Microphones $A$ and $B$ are mixed so that the sum combination $(A+B)$ is fed to the main channel of the FM transmitter and the difference combination, $(A-B)$ is fed to the sub-carrier channel. The sum combination is readily recognizable by its improved bass response since the difference combination results in a microphone directive array which tends to cancel lower frequencies.

At the receiver the outputs of the main channel discriminator and the sub-carrier adapter are fed to a mixing system utilizing a phase inverter such that one amplifier and speaker receives the combination,

$$(A+B)-(A-B)=2B$$

and the other amplifier and speaker:

$$(A+B)+(A-B)=2A$$

This addition and subtraction separates the individual microphone outputs from their sum-and-difference combinations just as though the $A$ and $B$ microphones fed the $A$ and $B$ speakers directly.

It will be noted that the program on the main channel of the transmitter is the desired $A+B$ combination of microphones which provides the compatible balanced program for the monaural listener. Since the sub-carrier channel is superaudible, the monaural listening is unimpaired by the stereo transmission.

## SIGNAL-TO-NOISE CHARACTERISTICS

With the sum-and-difference technique, the resulting signal fed to one loudspeaker is an addition of the signal from the main channel and that from the sub-carrier channel. This combination doubles the amplitude of the signal and adds the noises from the two channels by rms addition. The noise from the sub-carrier channel is so much greater than that on the main channel that the rms addition of the two noises results in a noise having an amplitude equal to that of the sub-carrier channel. Since the signals have been doubled and the noise is equal to that on the sub-carrier channel, the resulting signal-to-noise ratio fed to either loudspeaker input is equal to 6 db above the normal signal-to-noise ratio on the sub-carrier channel.

In a previous publication,[3] data was presented on stereo recordings which indicated that the level of the difference combination $(A-B)$ was approximately 10 db below that of the sum combination $(A+B)$. If such data were characteristic, an additional 10-db improvement would be realized with respect to the sub-carrier channel since the recombination at the receiver would call for a 10-db attenuation of the signal and noise from the sub-carrier channel. However, more recent measurements have shown that this early data was not characteristic and that the difference in level between the sum-and-difference combinations is negligible. The early data was taken from experimental tape recordings of rehearsals at Carnegie Hall by the late Harold T. Sherman. The conditions of recording were such that the distance between the orchestra and the microphones was unusually large. This results in a small phase difference between the pickup from the two microphones so that the difference combination tends to cancel on a wide range of frequencies. With modern stereo microphone placement techniques, the microphones are placed so close to the orchestra that the difference combination tends to cancel only the lowest frequencies and is therefore approximately the same level as the sum combination. Observations on a large number of present-day stereo tapes have confirmed this conclusion.

[3] Murray G. Crosby, *Binaural Sound on One FM Channel*, TV & Radio Engineering, Aug. and Sept. 1953.

## RECOMMENDED MODULATION STANDARDS

The present FCC rules for an FM Subsidiary Communications Authorization allow an application of 30 per cent of the available 75-kc deviation of the FM transmitter to be applied to the sub-carrier channel. Where the sub-carrier channel is to be used for directed background music or some other auxiliary service, this appears to be a practical value to protect the quality on the main program. However, where the transmitter is devoted wholly to broadcasting a stereo program, a division of modulation with at least 50 per cent modulation on the sub-carrier channel would appear to be more practical. This division considerably reduces cross modulation and also improves the signal-to-noise ratio on the sub-carrier channel. Such an improvement in signal-to-noise ratio is realized as an improvement in range and performance of the stereo broadcast since the sub-carrier signal-to-noise ratio dominates the system. The increase in loss on the main program from 3 db to 6 db would be scarcely noticeable in view of the relatively large signal-to-noise ratio present on the main channel.

The use of a single multiplex channel, with the complete transmitter devoted to stereo transmission only, is the optimum transmission system for many reasons. The first advantage is that the multiplex receiving adapter is the simplest possible since there is no requirement of separating multiplex channels. The adapter filter then only has the requirement of rejecting the main channel and selecting the sub-carrier. The second advantage is that all of the available modulation power for the sub-carrier may be concentrated on one channel without the requirement of sharing it with another sub-carrier. In addition there is more available spectrum for applying a relatively high frequency deviation to the sub-carrier to thereby obtain the maximum efficiency of the stereo transmission system. The third advantage is that there is sufficient spectrum to transmit the full fidelity of 15-kc modulation range the same as is applied to the main channel. The fourth advantage is that cross modulation problems are considerably simplified. The transmission of a third channel on a Subsidiary Communications Authorization increases the possible cross modulation situations from two to six. The required reduction in modulation level devoted to the sub-carriers, together with the lowered level of frequency deviation of the sub-carriers, further increases this problem. Receiver and transmitter maladjustments are then greatly emphasized since they may bring forth many possible combinations of cross modulation.

## Discussion

Q. Has anyone estimated the cost of the receiver adapter which would handle the system?

A. I would make an estimate, in low quantities, of around the $89.50 range. As the volume goes up, it should go below that.

Q. In the sum-and-difference transmission a different type of distortion acts on each channel. The difference product goes through a sub-carrier which distorts it by processes unique to the sub-carrier. This is different from the processes which add distortion to the sum product which goes through the main channel. In the receiver, these products are added to and subtracted from each other. Since the distortions are not highly correlated, the resultant distortion comes from the most distorted channel. Have you any data on the overall channel result which you get with typical signals using this system with a suitably designed receiver, or do you have any special conditions that you would impose on the receiver?

A. We found that we get more distortion on the main channel than we do on the sub-carrier, so that the resulting distortion in the stereo system would be that present in the main channel.

Q. Can you give me any idea of the accuracy of summation and subtraction required in the transmitter and receiver?

A. That is concerned with the degree of cross modulation this system will stand. It is a balance, and I would say 20 db would be a normal value.

Q. As I understand it, most of the noise occurs on the $A-B$ channel, as you currently use the system. One loudspeaker receives the $(A+B)+(A-B)$, and the other $(A+B)-(A-B)$. Therefore with regard to the noise, the two speakers are out of phase. However, I think you could add and subtract them in a slightly different manner which would make them in phase with regard to this noise signal. I was curious as to whether the noise would be more objectionable in the latter situation.

A. I don't think there would be a particle of difference. We have made that switch, where the phase was changed to try to get the monaural reception right in the center. There is a wrong and a right phase in this case, but the noise characteristics just weren't different.

Q. What does $A-B$ alone sound like?

A. It is lacking in low frequencies. This is a directive pattern situation, such that the low frequencies cancel out, and it is fairly easy to determine by mere listening. In the case of $A+B$, the low frequencies add.

Q. What sort of cross modulation do you get between the two channels at the output end? Suppose a different program were transmitted on each channel.

A. With our sub-carrier system, the cross modulation is far better than 35 or 40 db at low frequencies, but gets poorer at the high frequencies. It is a matter of expense in filter design. Since stereo will stand just so much cross modulation, it becomes a matter of making the decision: Should we overdo the filter and make the receiver too expensive, or should we make a more practical compromise?

Q. Has the F.C.C. taken any position, or indicated serious interest, in this as a possible adoption by the broadcast field?

A. No, but they know about it. I submitted this system when they had their docket out on multiplex transmission, and it has been in their files for some time. I do know that in allowing stations to put stereo on the air, they have cautioned about impairing one program with respect to the other, such as putting highs on one channel and the lows on the other. The sum-and-difference technique is compatible with their attitude since the reception of the monaural listener would not be impaired if the sum were fed into the main channel.

## THE AUTHOR

Murray G. Crosby received the B.S. Degree in Electrical Engineering from the University of Wisconsin in 1927. For 20 years after his graduation from college, he was research engineer for RCA Laboratories at Riverhead, L. I., New York. After leaving RCA Laboratories, he was associated with Paul Godley Co., Consulting Engineers, for approximately three years. In 1948 he set up his own business, Crosby Laboratories, Inc., which is now located in Hicksville, L. I., New York.

He is the author of about a dozen technical articles on the subjects of frequency and phase modulation and is the inventor of about 180 patents in that field. Mr. Crosby is a licensed Professional Engineer in New York State.

# EXHIBIT 5

SECTION 11A: CONVENTIONAL, ENHANCED AND HIGH-DEFINITION TELEVISION SYSTEMS

# RECOMMENDATION ITU-R BT.470-4*

## TELEVISION SYSTEMS

(Question ITU-R 1/11)

(1970-1974-1986-1994-1995)

The ITU Radiocommunication Assembly,

*considering*

a) that many countries have established satisfactory monochrome television broadcasting services based on either 525-line or 625-line systems;

b) that a number of countries have established (or are in the process of establishing) satisfactory colour television broadcasting services based on the NTSC, PAL or SECAM systems;

c) that the use of video component signals, signals consisting of the luminance and two colour difference signals, with time compression and time division multiplexing, may offer picture quality benefits, using new types of television receivers;

d) that it would add further complications to the interchange of programmes to have a greater multiplicity of systems,

*recommends*

1 that, for a country wishing to initiate a monochrome television service, a system using 525- or 625-lines as defined in Annex 1 is to be preferred;

2 that, for monochrome 625-line systems, the video-frequency characteristic described in Recommendation ITU-R BT.472 is to be preferred;

3 that, for a country wishing to initiate a colour television service, one of the systems defined in Annex 1 is to be preferred. However, other systems based on the use of video components that have been defined in Recommendation ITU-R BO.650 for satellite broadcasting can be considered.

NOTE 1 – Pre-1986 editions of the ex-CCIR Volumes, and in particular that of 1982, contain a complete description of system E used in France until 1984, and system A used in the United Kingdom until 1985.

AX204694

* New television systems intended for satellite broadcasting are covered in Recommendation ITU-R BO.650.

ANNEX 1

## Characteristics of television systems

The following tables, given for information purposes, contain details of a number of different television systems in use at the time of the XVIIth Plenary Assembly of the CCIR, Düsseldorf, 1990.

A list of countries and geographical areas, and the television systems used, are given in Appendix 1.

Specifications of the SECAM IV colour television system, which is still under consideration, are given in Appendix 2.

Information on the results of the comparative laboratory tests carried out on the various colour television systems in the period 1963-1966 by broadcasting authorities, administrations and industrial organizations, together with the main parameters of systems may be found in Reports 406 and 407, XIIth Plenary Assembly, New Delhi, 1970.

All television systems listed in this Annex employ an aspect ratio of the picture display (width/height) of 4/3, a scanning sequence from left to right and from top to bottom and an interlace ratio of 2/1, resulting in a picture (frame) frequency of half the field frequency. All systems are capable of operating independently of the power supply frequency.

TABLE 1

**Basic characteristics of video and synchronizing signals**

| Item | Characteristics | System | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | M | N[1] | B, G | H | I | D, K | K1 | L | Rec. ITU-R BT.472[2] |
| 1 | Number of lines per picture (frame) | 525 | 625 | 625 | 625 | 625 | 625 | 625 | 625 | 625 |
| 2 | Field frequency, nominal value (field/s)[3] | 60 (59.94) | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| 3 | Line frequency $f_H$ and tolerance when operated non-synchronously (Hz)[3], [4] | 15 750 (15 734.264 ±0.0003%) | 15 625 ±0.15% (±0.00014%) | 15 625[5] ±0.02% (±0.0001%) | 15 625 ±0.02% (±0.0001%) | 15 625 ±0.00002%[6] | 15 625[5] ±0.02% (±0.0001%) | 15 625 ±0.02% (±0.0001%) | 15 625 ±0.02% (±0.0001%) | 15 625 ±0.02% (±0.0001%) |
| 3 a) | Maximum variation rate of line frequency valid for monochrome transmission (%/s)[7], [8] | 0.15 | | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | |
| 4[9] | Nominal and peak levels of the composite video signal (%)( (see Fig. 1) | | | | | | | | | |
| | Blanking level (reference level) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | Peak white-level | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | |
| | Synchronizing level | −40 | −40 (−43) | −43 | −43 | −43 | −43 | −43 | −43 | |
| | Difference between black and blanking level | 7.5 ± 2.5[10] | 7.5 ± 2.5 (0) | 0 | 0 | 0 | 0-7 | 0 (colour) 0-7 (mono.) | 0 (colour) 0-7 (mono.) | $0^{+5}_{-0}$ |
| | Peak level including chrominance signal | 120 | | 133[11] | | 133 | 115[12] | 115[12] | 124[12] | |
| 5 | Assumed gamma of display device for which pre-correction of monochrome signal is made | 2.2 | 2.2 (2.8) | 2.8[13] | | | | | | [14] |
| 6 | Nominal video bandwidth (MHz) | 4.2 | 4.2 | 5 | 5 | 5.5 | 6 | 6 | 6 | 5.0 or 5.5 or 6.0 |
| 7 | Line synchronization | see Table 1-1 | | | | | | | | |
| 8 | Field synchronization | see Table 1-2 | | | | | | | | |

AX204696

*Notes to Table 1:*

(1) The values in brackets apply to the combination N/PAL used in Argentina.

(2) Figures are given for comparison.

(3) Figures in brackets are valid for colour transmission.

(4) In order to take full advantage of precision offset when the interfering carrier falls in the sideband of the upper video range (greater than 2 MHz) of the wanted signal a line-frequency stability of at least $2 \times 10^{-7}$ is necessary.

(5) The exact value of the tolerance for line frequency when the reference of synchronism is being changed requires further study.

(6) When the reference of synchronism is being changed, this may be relaxed to 15 625 ± 0.02%.

(7) These values are not valid when the reference of synchronism is being changed.

(8) Further study is required to define maximum variation rate of line frequency valid for colour transmission. In the United Kingdom and Japan this is 0.1 Hz/s.

(9) It is also customary to define certain signal levels in 625-line systems, as follows:

Synchronizing level = 0
Blanking level = 30
Peak white-level = 100

For this scale, the peak level including chrominance signal for system D, K/SECAM equals 110.7. According to common studio operating practices, peak white-level = 100 corresponds to 1.0 V measured across a matched 75 Ω termination.

(10) In Japan values $0^{+10}_{-0}$ are used.

(11) Value applies to PAL signals.

(12) Values apply to SECAM signals. For programme exchange the value is 115.

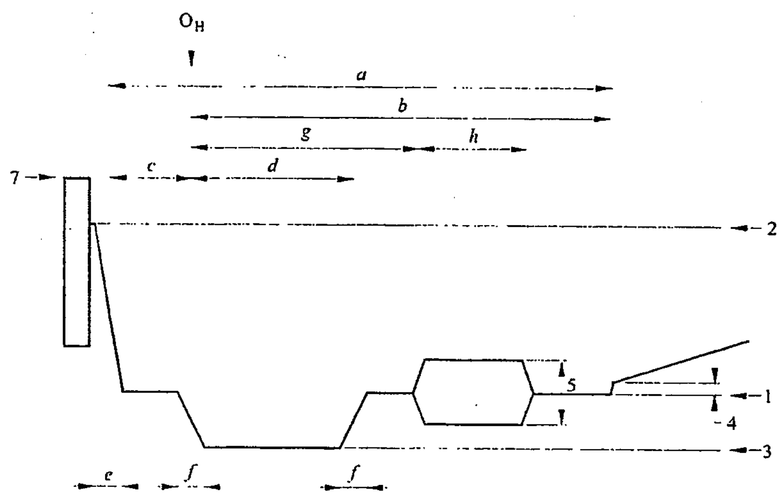
(13) Assumed value for overall gamma approximately 1.2. The gamma of the picture tube is defined as the slope of the curve giving the logarithm of the luminance reproduced as a function of the logarithm of the video signal voltage when the brightness control of the receiver is set so as to make this curve as straight as possible in a luminance range corresponding to a contrast of at least 1/40.

(14) In Recommendation ITU-R BT.472, a gamma value for the picture signal is given as approximately 0.4.

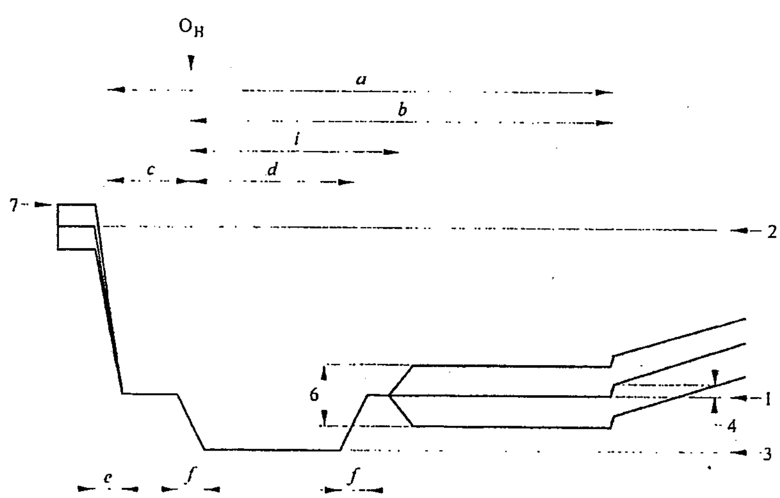
AX204697

FIGURE 1

**Levels in the composite signal and details of line-synchronizing signals**




a) NTSC and PAL systems




b) SECAM system

1 Blanking level
2 Peak white-level
3 Synchronizing level
4 Difference between black and blanking levels
5 Peak-to-peak value of burst
6 Peak-to-peak value of colour sub-carrier
7 Peak level including chrominance signal

TABLE 1-1

**Details of line synchronizing signals (see Fig. 1)**

Durations (measured between half-amplitude points on the appropriate edges) for various systems

| Symbol | Characteristics | M(1) | N(2) | B, G, H, I, D, K, K1, L (see also Rec. ITU-R BT.472) |
|---|---|---|---|---|
| H | Nominal line period (μs) | 63.492 (63.5555) | 64 | 64(3) |
| *a* | Line-blanking interval (μs) | 10.2 to 11.4(4) (10.9 ± 0.2) | (10.24 to 11.52 (12 ± 0.3) | 12 ± 0.3(5) |
| *b* | Interval between time datum ($O_H$) and back edge of line-blanking pulse (μs) | 8.9 to 10.3 (9.2 to 10.3) | 8.96 to 10.24 (10.5) | 10.5(6) |
| *c* | Front porch (μs) | 1.27 to 2.54 (1.27 to 2.22) | 1.28 to 2.56 (1.5 ± 0.3) | 1.5 ± 0.3(5), (7) |
| *d* | Synchronizing pulse (μs) | 4.19 to 5.71(4) (4.7 ± 0.1) | 4.22 to 5.76 (4.7 ± 0.2) | 4.7 ± 0.2 |
| *e* | Build-up time (10 to 90%) of the edges of the line-blanking pulse (μs) | ≤ 0.64 ≤ 0.48 | ≤ 0.64 (0.3 ± 0.1) | 0.3 ± 0.1 |
| *f* | Build-up time (10 to 90%) of the edges of the line-synchronizing pulses (μs) | ≤ 0.25 | ≤ 0.25 (0.2 ± 0.1) | 0.2 ± 0.1(8) |

(1) Values in brackets apply to M/NTSC.

(2) The values in brackets apply to the combination N/PAL used in Argentina.

(3) In France, and the countries of the OIRT, the tolerance for the instantaneous line period value is ± 0.032 μs.

(4) In Japan, the values in brackets apply to studio facilities.

(5) In 625-line countries using Teletext System B as specified in Annex 1 to Recommendation ITU-R BT.653 to reduce the possibilities of data loss, the following values are preferred:

*a*: line blanking interval: $12^{+0.0}_{-0.3}$ μs.

*c*: front porch: $1.5^{+0.3}_{-0.0}$ μs.

(6) Average calculated value, for information. For system I the value is 10.4.

(7) For system I, the values are 1.65 ± 0.1.

(8) For system I, the values are 0.25 ± 0.05.

AX204699

FIGURE 2

**Details of field-synchronizing waveforms**

FIGURES 2-1

**Diagrams applicable to all systems except M**

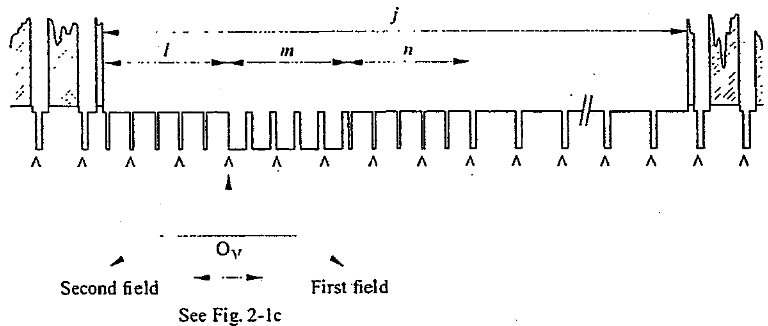



FIGURE 2-1a – Signal at the beginning of each first field

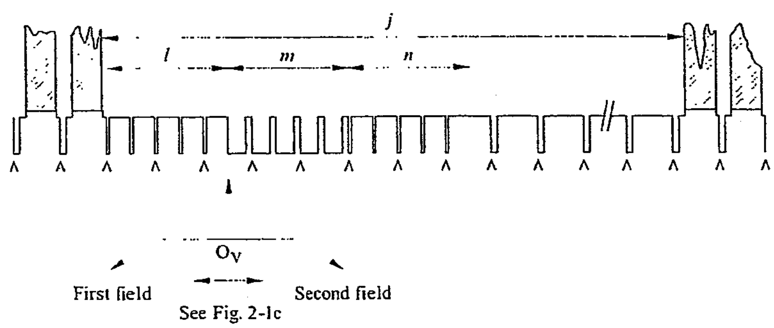


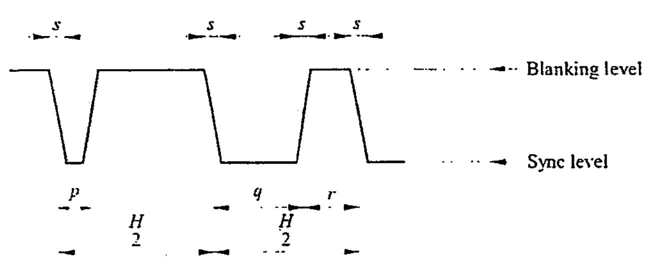

FIGURE 2-1b – Signal at the beginning of each second field

*Note 1* – ΛΛΛ indicates an unbroken sequence of edges of line-synchronizing pulses throughout the field-blanking period.

*Note 2* – At the beginning of each first field, the edge of the field-synchronizing pulse, $O_V$, coincides with the edge of a line-sychronizing pulse if *l* is an odd number of half-line periods as shown.

*Note 3* – At the beginning of each second field, the edge of the field-synchronizing pulse, $O_V$, falls midway between the edges of two line-synchronizing pulses if *l* is an odd number of half-line periods as shown.

*Note 4* – The dominant field is defined as that field of the video waveform at which a change of picture material should occur. The change of picture information should occur at the beginning of the first field.




(The durations are measured between the half-amplitude points on the appropriate edges)

FIGURE 2-1c – Details of equalizing and synchronizing pulses

D02

FIGURE 2

**Details of field-synchronizing waveforms**

FIGURES 2-2

**Diagrams applicable to system M**

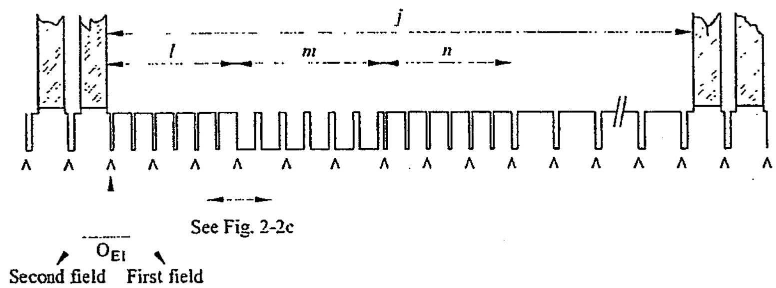



FIGURE 2-2a – Signal at the beginning of each first field

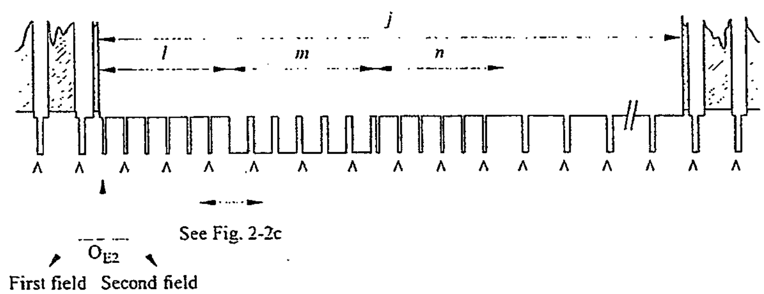



FIGURE 2-2b – Signal at beginning of each second field

*Note* 1 – ∧ indicates an unbroken sequence of edges of line-synchronizing pulses throughout the field-blanking period.

*Note 2* – Field-one line numbers start with the first equalizing pulse in Field 1, designated $O_{E1}$ in Fig. 2-2a.

*Note 3* – Field-two line numbers start with the second equalizing pulse in Field 2, one-half-line period after $O_{E2}$ in Fig. 2-2b.

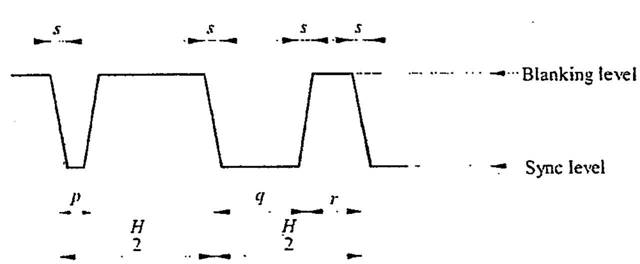



FIGURE 2-2c – Details of equalizing and synchronizing pulses

D03

AX204701

TABLE 1-2

**Details of field synchronizing signals (see Fig. 2)**

Duration (measured between half-amplitude points on the appropriate edges) for various systems

| Symbol | Characteristics | M | N[1] | B, G, H, I, D, K, K1, L (see also Rec. ITU-R BT.472) |
|---|---|---|---|---|
| v | Field period (ms) | 16.667[2] (16.6833) | 20 | 20 |
| $j$ | Field-blanking interval (for $H$ and $a$, see Table 1-1) | (19 to 21) $H+a$[3] | (19 to 25) $H+a$ (25 $H+a$) | 25 $H+a$ |
| $j'$[4] | Build-up time (10 to 90%) of the edges of field-blanking pulses (µs) | ≤ 6.35 | ≤ 6.35 (0.3 ± 0.1) | 0.3 ± 0.1 |
| $k$[4] | Interval between front edge of field-blanking interval and front edge of first equalizing pulse (µs) | (1.5 ± 0.1) | | 3 ± 2[5] (systems B/SECAM, G/SECAM, D, K, K1 and L only; no ref. in Rec. ITU-R BT.472) |
| $l$ | Duration of first sequence of equalizing pulses | 3 $H$ | 3 $H$ (2.5 $H$) | 2.5 $H$ |
| $m$ | Duration of sequence of synchronizing pulses | 3 $H$ | 3 $H$ (2.5 $H$) | 2.5 $H$ |
| $n$ | Duration of second sequence of equalizing pulses | 3 $H$ | 3 $H$ (2.5 $H$) | 2.5 $H$ |
| $p$ | Duration of equalizing pulse (µs) | (2.3 ± 0.1)[6] | 2.30 to 2.56 (2.35 ± 0.1) | (2.35 ± 0.1) |
| $q$ | Duration of field-synchronizing pulse (µs) | 27.1 (nominal value) | 26.52 to 28.16 (27.3) | 27.3[7] (nominal value) |
| $r$ | Interval between field-synchronizing pulse (µs) | (4.7 ± 0.1) | 3.84 to 5.63 (4.7 ± 0.2) | (4.7 ± 0.2)[8] |
| $s$ | Build-up time (10 to 90%) of synchronizing and equalizing pulses (µs) | ≤ 0.25 | ≤ 0.25 (0.2 ± 0.1) | (0.2 ± 0.1)[9] |

(1) The values in brackets apply to the combination NPAL used in Argentina.

(2) The value in brackets applies to the M/NTSC system.

(3) The value $0.07\,v^{+0.012\,v}_{-0}$ is used in Japan where v is the field period.

(4) Not indicated in the diagram.

(5) This value is to be specified more precisely at a later date.

(6) The following specification is also applied in Japan: an equalizing pulse has 0.45 to 0.5 times the area of a line-synchronizing pulse.

(7) For system I: 27.3 ± 0.1.

(8) For system I: 4.7 ± 0.1.

(9) For system I: 0.25 ± 0.05.

TABLE 2

**Characteristics of video signal for colour television**

| Item | Characteristics | Colour television system | | | | | |
|---|---|---|---|---|---|---|---|
| | | M/NTSC | M/PAL | B, D, G, H, N/PAL | I/PAL | B, D, G, H, K, K1, L/SECAM | N/PAL[1] |
| 2.1 | Assumed chromaticity coordinates (CIE, 1931) for primary colours of receiver | $x$ $y$<br>Red 0.67 0.33<br>Green 0.21 0.71<br>Blue 0.14 0.08 | | $x$ $y$<br>Red 0.64 0.33<br>Green 0.29 0.60<br>Blue 0.15 0.06 (2) | | | |
| 2.2 | Chromaticity coordinates for equal primary signals $E'_R = E'_G = E'_B$ | Illuminant $C$<br>$x = 0.310$<br>$y = 0.316$ (3) | | Illuminant $D_{65}$<br>$x = 0.313$<br>$y = 0.329$ (2) | | | |
| 2.3 | Assumed gamma value of the receiver for which the primary signals are pre-corrected (4) | 2.2 | 2.8 | | | | |
| 2.4 | Luminance signal | $E'_Y = 0.299\ E'_R + 0.587\ E'_G + 0.114\ E'_B$ (5)<br>$E'_R$, $E'_G$ and $E'_B$ are gamma - pre-corrected primary signals (6) | | | | | |
| 2.5 | Chrominance signals (colour difference) | $E'_I = -0.27\,(E'_B - E'_Y) + 0.74\,(E'_R - E'_Y)$<br>$E'_Q = 0.41\,(E'_B - E'_Y) + 0.48\,(E'_R - E'_Y)$ | $E'_U = 0.493\,(E'_B - E'_Y)$<br>$E'_V = 0.877\,(E'_R - E'_Y)$ | | | $D'_R = -1.902\ (E'_R - E'_Y)$<br>$D'_B = 1.505\ (E'_B - E'_Y)$ | |
| 2.6 | Attenuation of colour difference signals | dB MHz<br>$E'_I \begin{cases} < 3 \text{ at } 1.3 \\ \geq 20 \text{ at } 3.6 \end{cases}$<br>$E'_Q \begin{cases} < 2 \text{ at } 0.4 \\ < 6 \text{ at } 0.5 \\ \geq 6 \text{ at } 0.6 \end{cases}$ | dB MHz<br>$E'_U$ $E'_V$ $\begin{cases} < 2 \text{ at } 1.3 \\ > 20 \text{ at } 3.6 \end{cases}$ | dB MHz<br>$E'_U$ $E'_V$ $\begin{cases} < 3 \text{ at } 1.3 \\ > 20 \text{ at } 4 \end{cases}$ | | dB MHz<br>$D'_R$ $D'_B$ $\begin{cases} \leq 3 \text{ at } 1.3 \\ \geq 30 \text{ at } 3.5 \end{cases}$<br>Low frequency pre-correction not taken into account (7) | dB MHz<br>$E'_U < 3$ at 1.3<br>$E'_V > 20$ at 3.6 |

See Notes at the end of Table 2.

AX204703

TABLE 2 *(continued)*

| Item | Characteristics | Colour television system | | | | | |
|---|---|---|---|---|---|---|---|
| | | M/NTSC | M/PAL | B, D, G, H, N/PAL | I/PAL | B, D, G, H, K, K1, L/SECAM | N/PAL[1] |
| 2.7 | Low frequency pre-correction of colour difference signals | | | | | For sinusoidal signals:<br>$D'^*_R = A_{BF}(f)\, D'_R$<br>$D'^*_B = A_{BF}(f)\, D'_B$<br>$A_{BF}(f) = \frac{1 + j(f/f_1)}{1 + j(f/3f_1)}$<br>$f$: signal frequency (kHz)<br>$f_1 = 85$ kHz<br>(See Fig. 6 for the amplitude response)[8] | |
| 2.8 | Time-coincidence error between luminance and chrominance signals (μs) | < 0.05<br>Excluding pre-correction for receiver response | | | | | |
| 2.9 | Equation of composite colour signal | $E_M = E'_Y +$<br>$+ E'_Q \sin(2\pi f_{sc} + 33°) +$<br>$+ E'_I \cos(2\pi f_{sc} + 33°)$<br>where:<br>$E'_Y$, see item 2.4<br>$E'_Q$ and $E'_I$, see item 2.5<br>$f_{sc}$, see item 2.11<br>(See also Fig. 4a) | $E_M = E'_Y + E'_U \sin 2\pi f_{sc} \pm E'_V \cos 2\pi f_{sc}$<br>where:<br>$E'_Y$, see item 2.4<br>$E'_U$ and $E'_V$, see item 2.5<br>$f_{sc}$, see item 2.11<br>The sign of the $E'_V$ component is the same as that of the sub-carrier burst (changing for each line) (see item 2.16 and Fig. 4b) | | | $E_M = E'_Y + G \cos 2\pi (f_{OR} + \Delta f_{OR} \int_0^t D'^*_R\, dt)$<br>or $E_M = E'_Y + G \cos 2\pi (f_{OB} + \Delta f_{OB} \int_0^t D'^*_B\, dt)$<br>alternately from line to line<br>where:<br>$E'_Y$, see item 2.4<br>$f_{OR}$ and $f_{OB}$, see item 2.11<br>$\Delta f_{OR}$ and $\Delta f_{OB}$, see item 2.12<br>$D'^*_R$ and $D'^*_B$, see item 2.7<br>$G$, see item 2.13 | |
| 2.10 | Type of chrominance sub-carrier modulation | Suppressed-carrier amplitude-modulation of two sub-carriers in quadrature | | | | Frequency modulation | |

See Notes at the end of Table 2.

AX204704

TABLE 2 (*continued*)

| Item | Characteristics | Colour television system | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | M/NTSC | M/PAL | B, D, G, H, N/PAL | I/PAL | B, D, G, H, K, K1, L/SECAM | | | N/PAL[1] |
| 2.11 | Chrominance sub-carrier frequency<br>a) Nominal value and tolerance (Hz) | 3 579 545 ± 10 | 3 579 611.49 ± 10 | 4 433 618.75 ± 5 | 4 433 618.75 ± 1[9], [10] | $f_{OR}$ = 4 406 250 ± 2 000<br>$f_{OB}$ = 4 250 000 ± 2 000<br>[11] | | | 3 582 056.25 ± 5 |
| | b) Relationship between chrominance sub-carrier frequency $f_{sc}$ and line frequency $f_H$ | $f_{sc} = \frac{455}{2} f_H$ | $f_{sc} = \frac{909}{4} f_H$ | $f_{sc} = \left(\frac{1135}{4} + \frac{1}{625}\right) f_H$ | | Unmodulated sub-carrier at beginning of line<br>282 $f_H$ for $f_{OR}$<br>272 $f_H$ for $f_{OB}$ [12] | | | $f_{sc} = \left(\frac{917}{4} + \frac{1}{625}\right) f_H$ |
| 2.12 | Bandwidth of chrominance sidebands (quadrature modulation of sub-carrier) (kHz)<br>or<br>Frequency deviation of chrominance sub-carrier (frequency modulation of sub-carrier) (kHz) | $f_{sc}{}^{+620}_{-1300}$ | $f_{sc}{}^{+600}_{-1300}$ | $f_{sc}{}^{+570}_{-1300}$ [13] | $f_{sc}{}^{+1066}_{-1300}$ | | Nominal deviation $D'^* = 1$ [14] | Maximum deviation | $f_{sc}{}^{+620}_{-1300}$ |
| | | | | | | $\Delta f_{OR}$ [15] | 280 ± 9 (± 14) | +350 ± 18 (± 35)<br>−506 ± 25 (± 50) | |
| | | | | | | $\Delta f_{OB}$ [15] | 230 ± 7 (± 11.5) | +506 ± 25 (± 50)<br>−350 ± 18 (± 35) | |

See Notes at the end of Table 2.

AX204705

TABLE 2 *(continued)*

| Item | Characteristics | Colour television system | | | | | |
|---|---|---|---|---|---|---|---|
| | | M/NTSC | M/PAL | B, D, G, H, N/PAL | I/PAL | B, D, G, H, K, K1, L/SECAM | N/PAL[1] |
| 2.13 | Amplitude of chrominance sub-carrier | $G = \sqrt{E_I'^2 + E_Q'^2}$ | | $G = \sqrt{E_U'^2 + E_V'^2}$ (16), (17) | (16) | $G = M_0 \dfrac{1 + j\,16\,F}{1 + j\,1.26\,F}$ where the peak-to-peak amplitude, $2M_0$ is 23 ± 2.5 % of the luminance amplitude (between blanking level and peak-white) and $F = \dfrac{f}{f_0} - \dfrac{f_0}{f}$ where $f_0$ = 4 286 kHz and $f$ is the instantaneous sub-carrier frequency. The deviation of frequency, $f_0$, from its nominal value due to misalignment of the circuits concerned should not exceed ± 20 kHz. (See Fig. 7 for the amplitude response) | |
| 2.14 | Synchronization of chrominance sub-carrier | Sub-carrier burst on blanking back porch | Sub-carrier burst on blanking back porch | | | | |
| | g) Start of sub-carrier burst (µs) (see Fig. 1a) | 4.71 to 5.71 (5.3 nominal) at least 0.38 µs after the trailing edge of line synchronization signal | 5.8 ± 0.1 after epoch $O_H$ | 5.6 ± 0.1 after epoch $O_H$ (18) | | | |
| | h) Duration of sub-carrier burst (µs) (see Fig. 1a) | 2.23 to 3.11 (9 ± 1 cycles) | 2.52 ± 0.28 (9 ± 1 cycles) | 2.25 ± 0.23 (10 ± 1 cycles) | | | 2.51 ± 0.28 (9 ± 1 cycles) |

See Notes at the end of Table 2.

TABLE 2 *(continued)*

<table>
<tr><th rowspan="2">Item</th><th rowspan="2">Characteristics</th><th colspan="6">Colour television system</th></tr>
<tr><th>M/NTSC</th><th>M/PAL</th><th>B, D, G, H, N/PAL</th><th>I/PAL</th><th>B, D, G, H, K, K1, L/SECAM</th><th>N/PAL (1)</th></tr>
<tr><td>2.15</td><td>Peak-to-peak value of chrominance sub-carrier burst<br>(see Fig. 1a) (19)</td><td>4/10 of difference between blanking level and peak white-level ± 10%</td><td colspan="3">3/7 of difference between blanking level and peak white-level ± 10%<br>For systems D and I the tolerance is ± 3%<br>(16), (17) (16)</td><td></td><td></td></tr>
<tr><td>2.16</td><td>Phase of chrominance sub-carrier burst<br>(see Fig. 1a)</td><td>180° relative to $(E'_B - E'_Y)$ axis<br>(see Fig. 4a)<br>In the NTSC sequence of four colour fields, field 1 is identified in accordance with Note (20)<br>(see also Fig. 5c)</td><td colspan="3">135° relative to $E'_U$ axis with the following sign (see Fig. 4b)
<table>
<tr><td rowspan="4">Line</td><td colspan="8">Field No. (21)</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td></tr>
<tr><td colspan="8">Burst blanking sequence (see Figs. 5a and 5b)</td></tr>
<tr><td>I</td><td>II</td><td>III</td><td>IV</td><td>I</td><td>II</td><td>III</td><td>IV</td></tr>
<tr><td>Even<br>Odd</td><td>–<br>+</td><td>–<br>+</td><td>+<br>–</td><td>+<br>–</td><td>–<br>+</td><td>–<br>+</td><td>+<br>–</td><td>+<br>–</td></tr>
</table></td><td></td><td></td></tr>
<tr><td>2.17</td><td>Blanking of chrominance sub-carrier</td><td>Following each equalizing pulse and also during the broad synchronizing pulses in the field-blanking interval</td><td>11 lines of field-blanking interval:<br>260 to 270<br>522 to 7<br>259 to 269<br>233 to 8<br>(see Fig. 5b)</td><td colspan="2">9 lines of the field-blanking interval:<br>lines 311 to 319 inclusive<br>623 to 6 inclusive<br>310 to 318 inclusive<br>622 to 5 inclusive<br>(see Fig. 5a)</td><td>a) From leading edge of line-blanking signal up to $t = 5.6 \pm 0.2$ (µs) after epoch $O_H$,<br>i.e. during $c + i$<br>(see Fig. 1b) (22)<br>b) During field-blanking interval, excluding frame identification signals, or, in countries where this is possible, during the whole of the field-blanking interval (see item 2.18)</td><td></td></tr>
</table>

See Notes at the end of Table 2.

AX204707

TABLE 2 *(continued)*

| Item | Characteristics | Colour television system | | | | | |
|---|---|---|---|---|---|---|---|
| | | M/NTSC | M/PAL | B, D, G, H, N/PAL | I/PAL | B, D, G, H, K, K1, L/SECAM | N/PAL(1) |
| 2.18 | Synchronization of chrominance sub-carrier switching during line blanking | See item 2.16.<br>For signals used in programme integration, the tolerance on the coincidence between the reference sub-carrier and the horizontal synchronizing pulses in nominally 0 ± 40° of the reference sub-carrier | By $E'_V$ chrominance component of sub-carrier burst (see item 2.16) | | | In the SECAM system, one of two colour synchronization methods can be chosen:<br>– Line identification: by chrominance sub-carrier reference signals on the line-blanking back porch(23)<br>– By identification signals occupying 9 lines of field-blanking period:<br>a) line 7 to 15 in 1st and 3rd field<br>b) line 320 to 328 in 2nd and 4th field<br>(see Fig. 9)(24)<br>*Shape of video signals corresponding to identification signals:*<br>For lines $D'_R$ –<br>Trapezoid with linear variation from beginning of line on 15 ± 5 µs from 0 up to level +1.25 and then constant at the level +1.25 ± 0.06 (± 0.13)<br>(see Fig. 8) | |

See Notes at the end of Table 2.

AX204708

TABLE 2 *(continued)*

| Item | Characteristics | Colour television system | | | | | |
|---|---|---|---|---|---|---|---|
| | | M/NTSC | M/PAL | B, D, G, H, N/PAL | I/PAL | B, D, G, H, K, K1, L/SECAM | N/PAL[1] |
| | | | | | | For lines $D'_B$ – Trapezoid with linear variation from the beginning of the line on 18 ± 6 µs (20 ± 10 µs) from 0 down to level −1.52 and then constant at the level −1.52 ± 0.07 (± 0.15) (see Fig. 8)[15] *Peak-to-peak amplitude of identification signals:* For lines $D'_B$: 500 ± 50 mV For lines $D'_R$: $500^{+40mV}_{-50mV}$ if amplitude of luminance signal (between blanking level and peak white) equals 700 mV *Maximum deviation during transmission of identification signals (kHz):* For lines $D'_R$: +350 ± 18 (±35) For lines $D'_B$: −350 ± 18 (±35) [15] | |

See Notes at the end of Table 2.

AX204709

*Notes to Table 2:*

(1) These values apply to the combination N/PAL used in Argentina. Only those values are given in this column which are different from the values given in the column B, G, H, N/PAL.

(2) For SECAM systems and for existing sets, it is provisionally allowed to use the following chromaticity coordinates for the primary colours and white:

| | $x$ | $y$ | |
|---|---|---|---|
| Red | 0.67 | 0.33 | |
| Green | 0.21 | 0.71 | |
| Blue | 0.14 | 0.08 | |
| White | 0.310 | 0.316 | (C-white) |

(3) In Japan, the chromaticity of studio monitors is adjusted to a D-white at 9300 K.

(4) The primary signals are pre-corrected so that the optimum quality is obtained with a display having the indicated value of gamma.

(5) In certain countries using the SECAM systems and in Japan it is also permitted to obtain the luminance signal as a direct output from an independent photo-electric analyser instead of from the primary signals.

(6) For the SECAM system, it is allowable to apply a correction to reduce interference distortions between the luminance and chrominance signals by an attenuation of the luminance signal components as a function of the amplitude of the luminance components in the chrominance band.

(7) This value will be defined more precisely later.

(8) The maximum deviations from the nominal shape of the curve (see Fig. 6) should not exceed ± 0.5 dB in the frequency range from 0.1 to 0.5 MHz and ± 1.0 dB in the frequency range from 0.5 to 1.3 MHz.

(9) When the signal originates from a portable or overseas source the tolerance on the frequency may be relaxed to ± 5 Hz. Maximum rate of variation of $f_{sc}$ = 0.1 Hz/s.

(10) This tolerance may not be maintained during such operational procedures as "genlock".

(11) A reduction of the tolerance is desirable.

(12) The initial phase of the sub-carrier undergoes in each line a variation defined by the following rule:

From frame to frame: by 0°; 180°; 0°; 180°; and so on, and also from line to line in either one of the following two patterns:

0°; 0°; 180°; 0°; 0°; 180°; and so on,
or 0°; 0°; 0°; 180°; 180°; 180°; and so on.

(13) $f_{sc}$ ± 1 300 kHz is adopted in the People's Republic of China.

(14) The unity value represents the amplitude of the luminance signal between the blanking level and the peak white-level.

(15) Provisionally, the tolerances may be extended up to the values given brackets.

(16) During transmission of a monochrome programme of significant duration, in order to ensure satisfactory operation of colour-killers in receivers, all signals having the same nominal frequency as the colour sub-carrier that appears in the line-blanking interval, should be attenuated by at least 35 dB below the peak-to-peak value of the burst given in item 2.15, column 3 of Table 2, and shown as item 5 in Fig. 1.

(17) The value given in Note (16) is accepted on a tentative basis.

(18) Transmitter pre-correction for receiver group delay is not included.

(19) For the use of automatic gain control circuits, it is important that the burst amplitude should maintain the correct ratio with the chrominance signal amplitude.

(20) Field 1 of the sequence of four fields in the NTSC video signal is defined by a whole line between the first equalizing pulse and the preceding horizontal synchronizing pulse and a negative-going zero-crossing of the reference sub-carrier nominally at the 50% point of the first equalizing pulse. The zero-crossing of the reference sub-carrier shall be nominally coincident with the 50% point of the leading edges of all horizontal synchronizing pulses for programme integration at the studio.

(21) Field 1 of the sequence of eight colour fields is defined as that field, where the phase $\varphi\, E'_U$ of the extrapolated $E'_U$ component (see item 2.5 of Table 2) of the video burst at the half amplitude point of the leading edge of the line synchronizing pulse of line 1 is in the range $-90° \leq \varphi\, E'_U < 90°$.

(22) The value of the tolerance will be defined more precisely later.

(23) The line identification method is preferable, because it will enable agreements to be reached subsequently on the suppression of frame identification signals in international programme exchanges. In the absence of such agreements, signals meeting the SECAM standard are regarded as comprising such identification signals.

In France, a decree of 14 March 1978 specified that colour TV receivers placed on sale on or after 1 December 1979 must use the line identification method of decoding.

(24) The order in which the identification signals $D_R^*$ and $D_B^*$ appear on the four fields of a complete cycle given in Fig. 9 is in conformity with Recommendation ITU-R BR.469.

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TABLE 3

**Characteristics of the radiated signals (monochrome and colour)**

| Item | Characteristics | M | N[1] | B, G | H | I | D, K | K1 | L |
|---|---|---|---|---|---|---|---|---|---|
| | Frequency spacing (see Fig. 10) | | | | | | | | |
| 1 | Nominal radio-frequency channel bandwidth (MHz) | 6 | 6 | B:7<br>G:8 | 8 | 8 | 8 | 8 | 8 |
| 2 | Sound carrier relative to vision carrier (MHz) | +4.5[2] | +4.5 | +5.5<br>±0.001<br>(3), (4), (5), (6) | +5.5 | +5.9996<br>±0.0005[7] | +6.5<br>±0.001 | +6.5 | +6.5[8] |
| 3 | Nearest edge of channel relative to vision carrier (MHz) | −1.25 | −1.25 | −1.25 | −1.25 | −1.25 | −1.25 | −1.25 | −1.25 |
| 4 | Nominal width of main sideband (MHz) | 4.2 | 4.2 | 5 | 5 | 5.5 | 6 | 6 | 6[8] |
| 5 | Nominal width of vestigial sideband (MHz) | 0.75 | 0.75 | 0.75 | 1.25 | 1.25 | 0.75 | 1.25 | 1.25 |
| 6 | Minimum attenuation of vestigial sideband (dB at MHz)[9] | 20 (−1.25)<br>42 (−3.58) | 20 (−1.25)<br>42 (−3.5) | 20 (−1.25)<br>20 (−3.0)<br>30 (−4.43)<br>(10) | 20 (−1.75)<br>20 (−3.0) | 20 (−3.0)<br>30 (−4.43) | 20 (−1.25)<br>30 (−4.33<br>±0.1)<br>(11), (12) | 20 (−2.7)<br>30 (−4.3)<br>ref.: 0 (+0.8) | 15 (−2.7)<br>30 (−4.3)<br>ref.: 0 (+0.8) |
| 7 | Type and polarity of vision modulations | C3F neg. | C3F neg. | C3F neg. | C3F neg. | C3F neg. | C3F neg. | C3F neg. | C3F pos. |
| 8 | Levels in the radiated signal (% of peak carrier) | | | | | | | | |
| | Synchronizing level | 100 | 100 | 100 | 100 | 100 | 100 | 100 | < 6[8] |
| | Blanking level | 72.5 to 77.5 | 72.5 to 77.5<br>(75 ± 2.5) | 75 ± 2.5<br>(13) | 72.5 to 77.5 | 76 ± 2 | 75 ± 2.5 | 75 ± 2.5 | 30 ± 2 |
| | Difference between black level and blanking level | 2.88 to 6.75<br>(14) | 2.88 to 6.75 | 0 to 2<br>(nominal) | 0 to 7 | 0<br>(nominal) | 0 to 4.5<br>(15) | 0 to 4.5 | 0 to 4.5 |
| | Peak white-level | 10 to 15 | 10 to 15<br>(10 to 12.5) | 10 to 15<br>(13), (16) | 10 to 12.5 | 20 ± 2 | 10 to 12.5<br>(17), (18) | 10 to 12.5 | 100 (≈ 110)<br>(19) |
| 9 | Type of sound modulation | F3E | F3E | F3E | F3E | F3E | F3E | F3E | A3E |

See Notes at the end of Table 3.

TABLE 3 *(continued)*

| Item | Characteristics | M | N[1] | B, G | H | I | D, K | K1 | L |
|---|---|---|---|---|---|---|---|---|---|
| 10 | Frequency deviation (kHz) | ±25 | ±25 | ±50 | ±50 | ±50 | ±50 | ±50 | |
| 11 | Pre-emphasis for modulation (μs) | 75 | 75 | 50 | 50 | 50 | 50 | 50 | |
| 12 | Ratio of effective radiated powers of vision and (primary) sound[20] | 10/1 to 5/1 (21) | 10/1 to 5/1 | 20/1 to 10/1 (3), (6), (22) | 5/1 to 10/1 | 5/1<br>10/1 (7), (23)<br>20/1 (24) | 10/1 to 5/1 (25) | 10/1 | 10/1<br>10/1 to 40/1 (8), (26) |
| 13 | Pre-correction for receiver group-delay characteristics at medium video frequencies (ns) (see also Fig. 3) | 0 | (1 MHz 0 ± 100<br>1 MHz 0 ± 100<br>1 MHz 0 ± 60) | (27) | | | (28) | | |
| 14 | Pre-correction for receiver group-delay characteristics at colour sub-carrier frequency (ns) (see also Fig. 3) | −170 (nominal) | $\left(-170^{+60}_{-40}\right)$ | −170 (nominal) (27) | | | (29) | | |

(1) The values in brackets apply to the combination N/PAL used in Argentina.

(2) In Japan, the values +4.5 ± 0.001 are used.

(3) In the Federal Republic of Germany, Austria, Italy, the Netherlands and Switzerland a system of two sound carriers is used, the frequency of the second carrier being 242.1875 kHz above the frequency of the first sound carrier. The ratio between vision/sound e.r.p. for this second carrier is 100/1. For further information on this system see Recommendation ITU-R BS.707. For stereophonic sound transmissions a similar system is used in Australia with vision/sound power ratios being 20/1 and 100/1 for the first and second sound carriers respectively.

(4) New Zealand uses a sound carrier displaced 5.4996 ± 0.0005 MHz from the vision carrier.

(5) The sound carrier for single carrier sound transmissions in Australia may be displaced 5.5 ± 0.005 MHz from the vision carrier.

(6) In Denmark, Finland, New Zealand, Sweden and Spain a system of two sound carriers is used. In Iceland and Norway the same system is being introduced. The second carrier is 5.85 MHz above the vision carrier and is DQPSK modulated with 728 kbit/s sound and data multiplex. The ratios between vision/sound power are 20/1 and 100/1 for the first and second carrier respectively. For further information, see Recommendation ITU-R BS.707.

(7) In the United Kingdom, a system of two sound carriers is used. The second sound carrier is 6.552 MHz above the vision carrier and is DQPSK modulated with a 728 kbit/s sound and data multiplex able to carry two sound channels. The ratio between vision and sound e.r.p. for the second carrier is 100/1.

(8) In France, a digital carrier 5.85 MHz away from the vision carrier may be used in addition to the main sound carrier. It is modulated in differentially encoded QPSK with a 728 kbit/s sound and data multiplexer capable of carrying two sound channels. The nominal width of the main sideband is limited to 5.1 MHz. The depth of video modulation in the radiated signal is reduced to leave a residual radiated carrier level of 5 ± 2%. For further information, see Recommendation ITU-R BS.707.

(9) In some cases, low-power transmitters are operated without vestigial-sideband filter.

(10) For B/SECAM and G/SECAM: 30 dB at − 4.33 MHz, within the limits of ± 0.1 MHz.

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*Notes to Table 3 (continued)*

(11) In some countries, members of the OIRT, additional specifications are in use:

a) not less than 40 dB at −4.286 MHz ± 0.5 MHz,

b) 0 dB from −0.75 MHz to +6.0 MHz,

c) not less than 20 dB at ± 6.375 MHz and higher.

Reference: 0 dB at +1.5 MHz.

(12) In the People's Republic of China, the attenuation value at the point (−4.33 ± 0.1) has not yet been determined.

(13) Australia uses the nominal modulation levels specified for system I.

(14) In Japan, the values of 0 to 6.75 have been adopted.

(15) In the People's Republic of China, the values 0 to 5 have been adopted.

(16) Italy is considering the possibility of controlling the peak white-level after weighting the video frequency signal by a low-pass filter, so as to take account only of those spectrum components of the signal that are likely to produce inter-carrier noise in certain receivers when the nominal level is exceeded. Studies should be continued with a view to optimizing the response of the weighting filter to be used.

(17) The USSR has adopted the value 15 ± 2%.

(18) A new parameter "white level with sub-carrier" should be specified at a later date. For that parameter, the USSR has adopted the value of 7 ± 2%.

(19) The peak white-level refers to a transmission without colour sub-carrier. The figure in brackets corresponds to the peak value of the transmitted signal, taking into account the colour sub-carrier of the respective colour television system.

(20) The values to be considered are:

– the r.m.s. value of the carrier at the peak of the modulation envelope for the vision signal. For system L, only the luminance signal is to be considered. (See Note (15) above);

– the r.m.s. value of the unmodulated carrier for amplitude-modulated and frequency-modulated sound transmissions.

(21) In Japan, a ratio of 1/0.15 to 1/0.35 is used. In the United States, the sound carrier e.r.p. is not to exceed 22% of the peak authorized vision e.r.p.

(22) Recent studies in India confirm the suitability of a 20/1 ratio of effective radiated powers of vision and sound. This ratio still enables the introduction of a second sound carrier.

(23) The ratio 10/1 is used in the Republic of South Africa and in the United Kingdom.

(24) In the People's Republic of China, the value 10/1 has been adopted.

(25) In the United Kingdom it is planned to make a limited use of a ratio of 20/1 for the primary sound carrier on an experimental basis.

(26) In France, the ratios 10/1 and 40/1 are used.

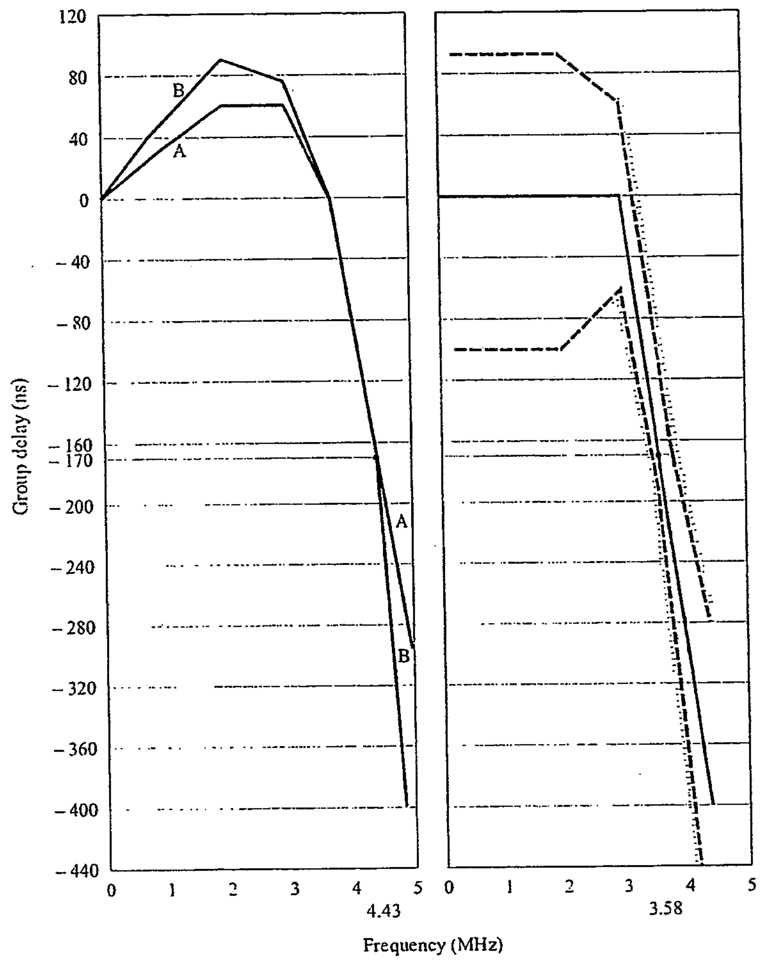
(27) In the Federal Republic of Germany and the Netherlands the correction for receiver group-delay characteristics is made according to curve B in Fig. 3a). Tolerances are shown in the table under Fig. 3a). Spain uses curve A. The OIRT countries using the B/SECAM and G/SECAM systems use a nominal pre-correction of 90 ns at medium video frequencies. In Sweden, the pre-correction is 0 ± 40 ns up to 3.6 MHz. For 4.43 MHz, the correction is −170 ± 20 ns and for 5 MHz it is −350 ± 80 ns. In New Zealand the pre-correction increases linearly from 0 ± 20 ns at 0 MHz to 60 ± 50 ns at 2.25 MHz, follows curve A of Fig. 3a) from 2.25 MHz to 4.43 MHz and then decreases linearly to −300 ± 75 ns at 5 MHz. In Australia, the nominal pre-correction follows curve A up to 2.5 MHz, then decreases to 0 ns at 3.5 MHz, −170 ns at 4.43 MHz and −280 ns at 5 MHz. Based on studies on receivers in India, the receiver group delay pre-equalization proposed to be adopted in India at 1 MHz, 2 MHz, 3 MHz, 4.43 MHz and 4.8 MHz is +125 ns, +150 ns, +142 ns, −75 ns and −200 ns respectively. In Denmark, the precorrections at 0, 0.25, 1.0, 2.0, 3.0, 3.8, 4.43 and 4.8 MHz are 0, +5, +53, +75, +75, 0, −170 and 400 ns.

(28) Not yet determined. The Czechoslovak Socialist Republic proposes +90 ns (nominal value).

(29) Not yet determined. The Czechoslovak Socialist Republic proposes +25 ns (nominal value).

FIGURE 3

Curve of pre-correction for receiver group-delay characteristics




a) B/PAL and G/PAL systems (See Table 3 (22))

b) M/PAL and M/NTSC systems

Nominal values and tolerances (ns)

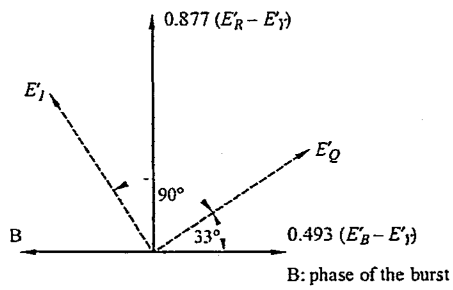
| Frequency (MHz) | Curve A | Curve B |
|---|---|---|
| 0.25 | | + 5 ± 0 |
| 1.00 | + 30 ± 50 | + 53 ± 40 |
| 2.00 | + 60 ± 50 | + 90 ± 40 |
| 3.00 | + 60 ± 50 | + 75 ± 40 |
| 3.75 | 0 ± 50 | 0 ± 40 |
| 4.43 | – 170 ± 35 | – 170 ± 40 |
| 4.80 | – 260 ± 75 | – 400 ± 90 |

D03

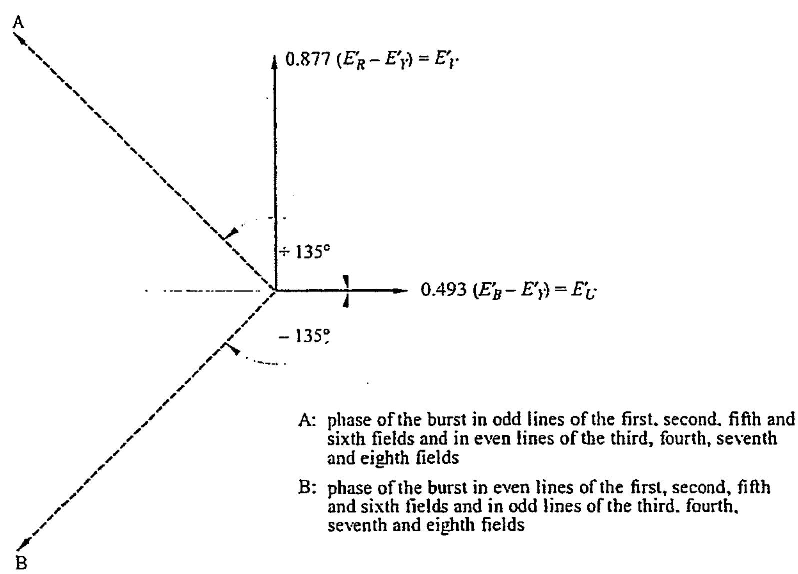
AX204714

FIGURE 4

**Chrominance axes and phase of the burst**




a) NTSC system



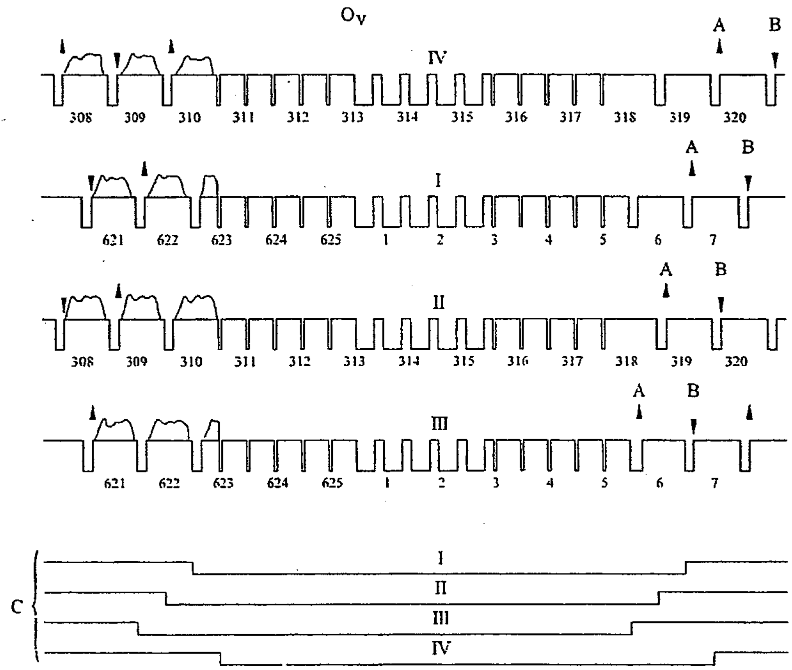

b) PAL system

D05

AX204715

FIGURE 5a

Burst-blanking sequence in the B, G, H and I/PAL systems




$O_V$: field-synchronizing datum

I, II, III, IV: first and fifth, second and sixth, third and seventh, fourth and eighth fields (see item 2.16 of Table 2)

A: phase of burst: nominal value +135°

B: phase of burst: nominal value −135°

C: burst-blanking intervals

D06

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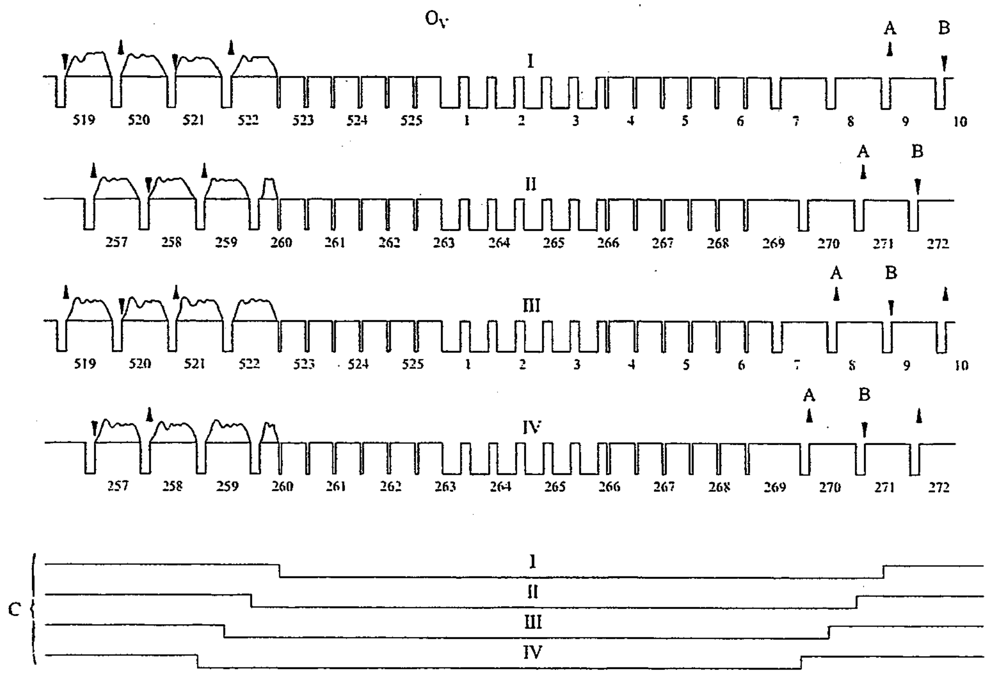
FIGURE 5b

**Burst-blanking sequence in M/PAL system**



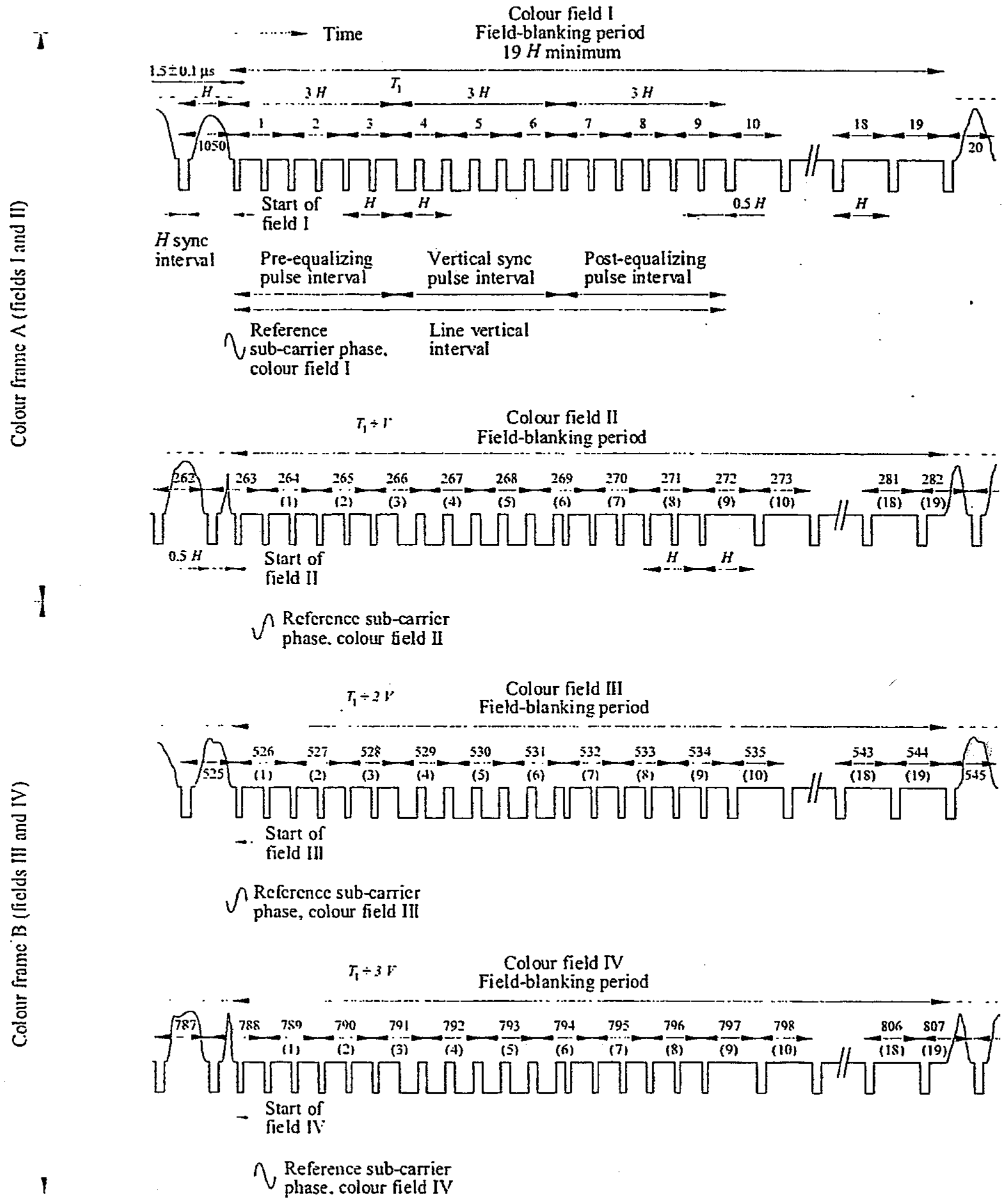

| | |
|---|---|
| $O_V$: | field-synchronizing datum |
| I, II, III, IV: | first and fifth, second and sixth, third and seventh, fourth and eighth fields (see item 2.16 of Table 2) |
| A: | phase of burst: nominal value +135° |
| B: | phase of burst: nominal value −135° |
| C: | burst-blanking intervals |

D07

AX204717

FIGURE 5c

**Burst-blanking sequence in M/NTSC system**



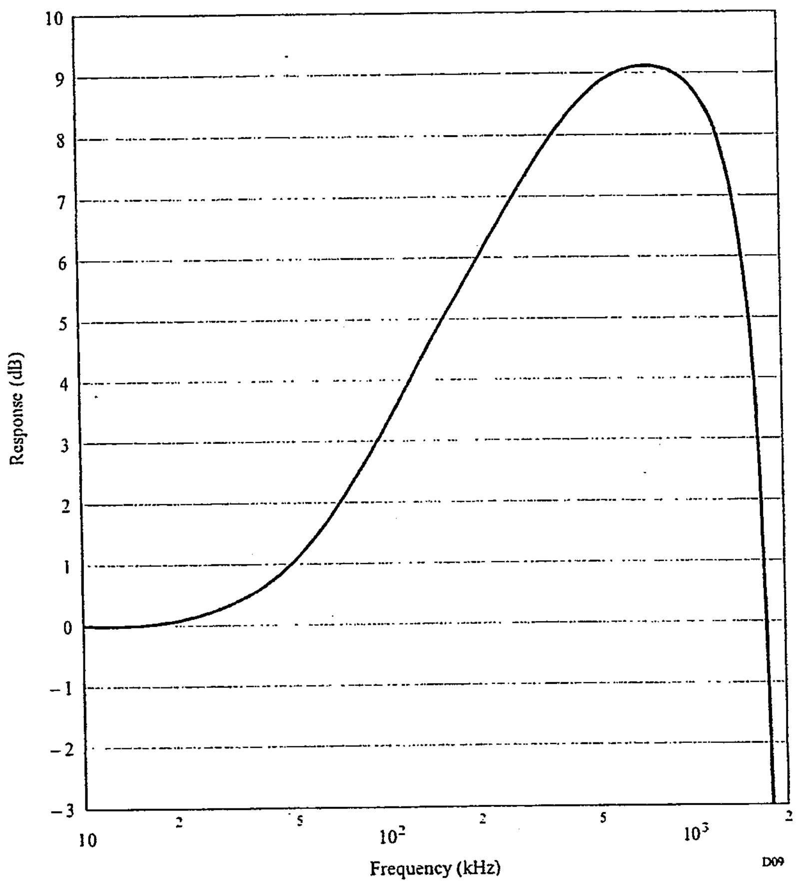

*Note 1* – The numbering of specific lines is in accordance with new engineering practice. Line numbers in parentheses ( ) represent an alternative method of line numbering used in some systems in some countries.

D08

AX204718

FIGURE 6

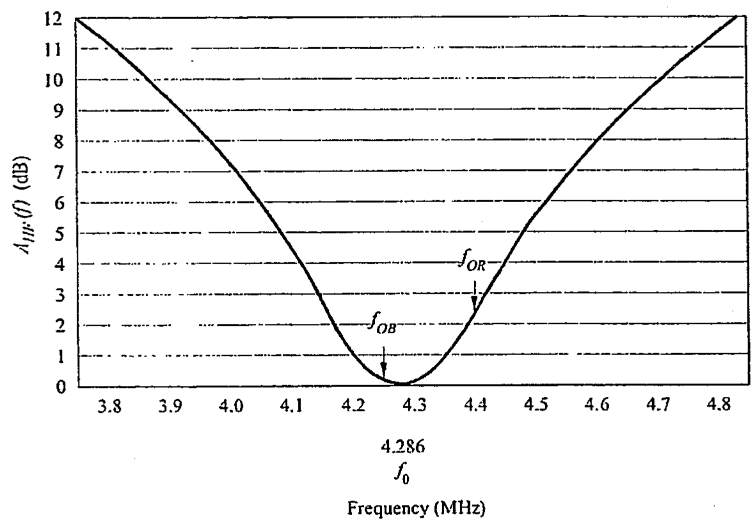
Nominal response of transfer function resulting from the video-frequency precorrection circuit $A_{BF}(f)$ and the low-pass filter (See Table 2, item 2.7)




AX204719

FIGURE 7

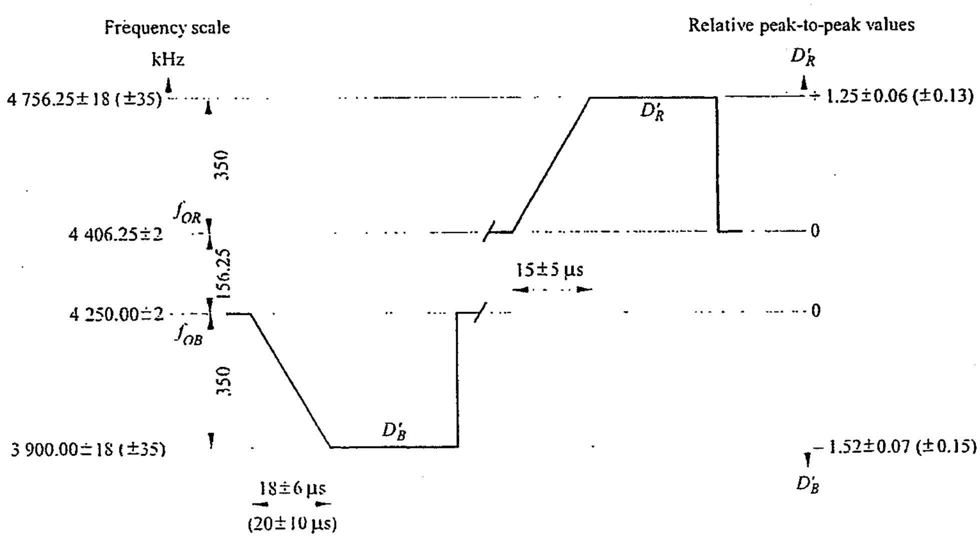
**Attenuation curve of frequency correction $A_{HF}(f)$**




Deviations from the nominal curve outside point $f_0$ must not exceed ± 0.5 dB. D10

FIGURE 8

**Shape of video signals corresponding to the chrominance synchronization signals**




The value 1 represents the amplitude of the luminance signal between the blanking level and the white level.
Provisionally, the tolerances may be extended up to the values given in brackets. D11

AX204720

FIGURE 9

Sequence of $D_R$* or $D_B$* signal over four consecutive fields

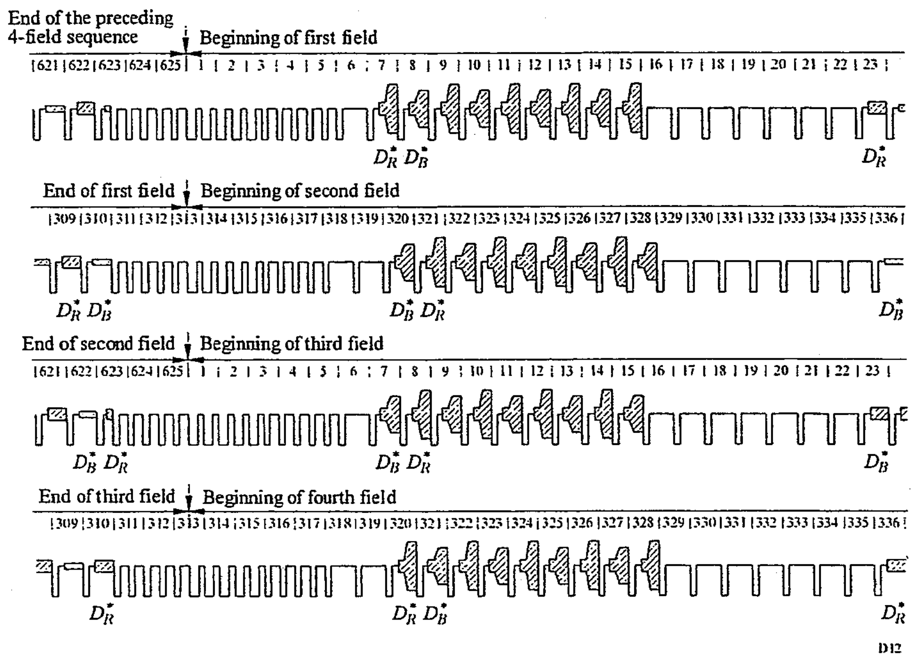
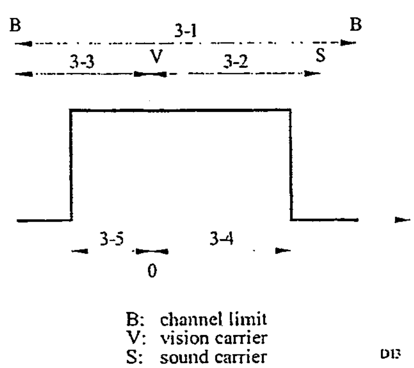



FIGURE 10

Significance of items 1 to 5 in Table 3 (3-1 to 3-5)




AX204721

APPENDIX 1

TO ANNEX 1

## Systems used in various countries/geographical areas

Explanation of signs used in the table:

* : planned (whether the standard is indicated or not);

** : updated in 1993, according to replies received from Administrations to Circular-letter 11/CL/3 dated 31 July 1992;

– : not yet planned, or no information received;

/ : the abbreviation following the stroke indicates the colour transmission system in use (NTSC, PAL or SECAM).

(Figures in brackets refer to the Notes following the table.)

**Television systems used in different countries/geographical areas**

| Country/Geographical area | | System used in bands: I/III VHF broadcasting (Band 8) | IV/V UHF broadcasting (Band 9) | |
|---|---|---|---|---|
| Afghanistan (Islamic State of) | | D/SECAM | – | |
| Albania (Republic of) | | | | |
| Algeria (People's Democratic Republic of) | (1) | B/PAL | G/PAL | (1) |
| Germany (Federal Republic of) | (2) | B/PAL | G/PAL | (2) |
| Angola (People's Republic of) | (1) | I/PAL | I/PAL* | (1) |
| Aruba** | | M/NTSC | M/NTSC | |
| Antigua and Barbuda | | | | |
| Saudi Arabia (Kingdom of) | | B/SECAM, PAL | G/SECAM | |
| Argentine Republic | | N/PAL | N/PAL | |
| Armenia (Republic of) | | | | |
| Australia | (3) | B/PAL | B/PAL | (3) |
| Austria** | (2) | B/PAL | G/PAL | (2) |
| Azerbaijani Republic | | | | |
| Bahamas (Commonwealth of the) | | | | |
| Bahrain (State of)** | | B/PAL | G/PAL | |
| Bangladesh (People's Republic of) | | B/PAL | – | |
| Barbados | | | | |
| Belarus (Republic of) | | | | |
| Belgium** | (4) | B/PAL | H/PAL | (4) |
| Belize** | | M/NTSC | – | |

AX204722

| Country/Geographical area | | System used in bands: | | | |
|---|---|---|---|---|---|
| | | I/III VHF broadcasting (Band 8) | IV/V UHF broadcasting (Band 9) | |
| Benin (Republic of) | (1) | K1/SECAM | K1/SECAM | (1) |
| Bermuda | | M/NTSC | – | |
| Bhutan (Kingdom of) | | | | |
| Bolivia (Republic of) | | M/NTSC | M/NTSC | |
| Bosnia and Herzegovina (Republic of) | | | | |
| Botswana (Republic of) | (1) | I/PAL | I/PAL* | (1) |
| Brazil (Federative Republic of) | | M/PAL | M/PAL | |
| Brunei Darussalam | | B/PAL | – | |
| Bulgaria (Republic of) | | D/SECAM | K/SECAM | |
| Burkina Faso | (1) | K1/SECAM | K1*SECAM | (1) |
| Burundi (Republic of) | (1) | K1/SECAM* | K1/SECAM* | (1) |
| Cambodia | | B/PAL | G*/PAL | |
| Cameroon (Republic of) | | B/PAL | G*/PAL | |
| Canada | | M/NTSC | M/NTSC | |
| Cape Verde (Republic of) | (1) | K1/SECAM* | K1/SECAM* | (1) |
| Central African Republic | (1) | K1/SECAM* | K1/SECAM* | (1) |
| Chile | | M/NTSC | M/NTSC | |
| China (People's Republic of) | | D/PAL | D/PAL | |
| Cyprus (Republic of)** | | B/PAL | G/PAL | |
| Vatican City State | | | | |
| Colombia (Republic of) | | M/NTSC | M* | |
| Comoros (Islamic Federal Republic of the) | (1) | K1SECAM* | K1/SECAM* | (1) |
| Congo (Republic of the) | (1) | K1/SECAM* | K1/SECAM* | (1) |
| Korea (Republic of) | | M/NTSC | M/NTSC | |
| Costa Rica | | M/NTSC | M/NTSC | |
| Côte d'Ivoire (Republic of) | (1) | K1/SECAM | K1/SECAM* | (1) |
| Croatia (Republic of)** | | B/PAL | G/PAL | |
| Cuba | | M/NTSC | M/NTSC | |
| Denmark | (4) | B/PAL | G/PAL | (4) |
| Djibouti (Republic of) | (1) | B/SECAM | – | (1) |
| Dominican Republic | | | | |
| Egypt (Arab Republic of) | (1) | B/PAL | G/PAL | (1) |

AX204723

| Country/Geographical area | | System used in bands: | | | |
|---|---|---|---|---|---|
| | | I/III VHF broadcasting (Band 8) | IV/V UHF broadcasting (Band 9) | |
| El Salvador (Republic of) | | M/NTSC | | |
| United Arab Emirates | | B/PAL | G/PAL | |
| Ecuador | | M/NTSC | M/NTSC | |
| Eritrea | | | | |
| Spain | (4) | B/PAL | G/PAL | (4) |
| Estonia (Republic of)** | | D/SECAM, B/PAL | K/SECAM, G/PAL | |
| United States of America** | | M/NTSC | M/NTSC | |
| Ethiopia | (1) | B,G/PAL | G/PAL* | (1) |
| Fiji (Republic of) | | | | |
| Finland | (4) | B/PAL | G/PAL | (4) |
| France | (5), (6) | L/SECAM | L/SECAM | (5), (6) |
| Gabonese Republic | (1) | K1/SECAM | K1/SECAM* | (1) |
| Gambia (Republic of the) | (1) | I/PAL | I/PAL* | (1) |
| Georgia (Republic of) | | | | |
| Ghana | (1) | B/PAL | B/PAL* | (1) |
| Gibraltar | | B/PAL | G/PAL | |
| Greece | | B/SECAM | G/SECAM | |
| Grenada | | | | |
| Guatemala (Republic of) | | | | |
| Guinea (Republic of) | (1) | K1/SECAM, PAL | K1/PAL* | (1) |
| Guinea-Bissau (Republic of) | (1) | I/PAL | I/PAL* | (1) |
| Equatorial Guinea (Republic of) | (1) | B/PAL | G/PAL* | (1) |
| Guyana | | | | |
| Haiti (Republic of) | | | | |
| Honduras (Republic of) | | | | |
| Hong Kong | | – | I/PAL | |
| Hungary (Republic of)** | | D/SECAM | K/SECAM | |
| India (Republic of) | | B/PAL | – | |
| Indonesia (Republic of) | | B/PAL | – | |
| Iran (Islamic Republic of) | | B/SECAM | G/SECAM | |
| Iraq (Republic of) | (1) | B,G/SECAM | G/SECAM* | (1) |
| Ireland | (7) | I/PAL | I/PAL | (7) |

AX204724

| Country/Geographical area | | System used in bands: I/III VHF broadcasting (Band 8) | | System used in bands: IV/V UHF broadcasting (Band 9) | |
|---|---|---|---|---|---|
| Iceland | (4) | B/PAL | | G* | (4) |
| Israel (State of) | | B/PAL | | G/PAL | (8) |
| Italy | (2) | B/PAL | | G/PAL | (2) |
| Jamaica | | N | | – | |
| Japan | | M/NTSC | | M/NTSC | |
| Jordan (Hashemite Kingdom of) | | B | | G* | |
| Kazakhstan (Republic of) | | | | | |
| Kenya (Republic of) | (1) | B/PAL | | B,G/PAL* | (1) |
| Kiribati (Republic of) | | | | | |
| Kuwait (State of) | (1) | B/PAL | | G/PAL* | (1) |
| Lao People's Democratic Republic | | | | | |
| Latvia (Republic of) | | | | | |
| Lesotho (Kingdom of) | (1) | I*/PAL | | I*/PAL | (1) |
| Lebanon | | | | | |
| Liberia (Republic of) | (1) | B/PAL | | G/PAL* | (1) |
| Libya (Socialist People's Libyan Arab Jamahiriya) | (1) | B,G/PAL | | B,G/PAL* | (1) |
| Lithuania (Republic of)** | | D/SECAM | | K/SECAM | |
| Liechtenstein (Principality of)** | | B/PAL | | G/PAL | |
| Luxembourg | | B/PAL | | G/PAL, L/SECAM | |
| Macau** | | – | | I/PAL | |
| Macedonia (Former Yugoslav Republic of) | | | | | |
| Madagascar (Democratic Republic of) | (1) | K1/SECAM | | K/SECAM* | (1) |
| Malaysia | | B/PAL | | G/PAL | |
| Malawi | (1) | I/PAL | | I/PAL* | (1) |
| Maldives (Republic of) | | B/PAL | | – | |
| Mali (Republic of) | (1) | B/SECAM | | G/SECAM* | (1) |
| Malta | | B/PAL | | – | |
| Morocco (Kingdom of) | (1) | B,G/SECAM | | G/SECAM | (1) |
| Mauritius (Republic of) | (1) | B,G/SECAM | | B,G/SECAM* | (1) |
| Mauritania (Islamic Republic of) | (1) | B/SECAM | | B/SECAM* | (1) |
| Mexico | | M/NTSC | | M/NTSC | |
| Micronesia (Federated States of) | | | | | |

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| Country/Geographical area | | System used in bands: | | | |
|---|---|---|---|---|---|
| | | I/III VHF broadcasting (Band 8) | IV/V UHF broadcasting (Band 9) | |
| Moldova (Republic of) | | | | |
| Monaco | | L/SECAM | G/PAL, G/SECAM | |
| Mongolia | | D/SECAM | – | |
| Montserrat | | M/NTSC | – | |
| Mozambique (Republic of) | (1) | G/PAL* | G/PAL | (1) |
| Myanmar (Union of)** | | M/NTSC | – | |
| Namibia (Republic of) | (1) | I/PAL | I/PAL | (1) |
| Nauru (Republic of) | | | | |
| Nepal | | | | |
| Nicaragua | | | | |
| Niger (Republic of the) | (1) | K1/SECAM | K1/SECAM | (1) |
| Nigeria (Federal Republic of) | (1) | B/PAL | I/PAL* | (1) |
| Norway | (4) | B/PAL | G/PAL | (4) |
| New Zealand | (4), (9) | B/PAL | G/PAL | (4), (9) |
| Oman (Sultanate of) | | B/PAL | G/PAL | |
| Uganda (Republic of) | (1) | B/PAL | – | (1) |
| Uzbekistan (Republic of) | | | | |
| Pakistan (Islamic Republic of) | | B/PAL | G/PAL | |
| Panama (Republic of) | | M/NTSC | M*/NTSC | |
| Papua New Guinea | | B/PAL | G/PAL | |
| Paraguay (Republic of) | | | | |
| Netherlands (Kingdom of the) | (2) | B/PAL | G/PAL | (2) |
| Peru | | M/NTSC | M/NTSC | |
| Philippines (Republic of the) | | | | |
| Poland (Republic of) | | D/PAL | K/PAL | |
| Portugal | | B/PAL | G/PAL | |
| Qatar (State of)** | | B/PAL | G/PAL | |
| Syrian Arab Republic | | B/PAL | G/PAL | |
| Democratic People's Republic of Korea | | D/PAL | K/PAL | |
| Slovak Republic | | D/SECAM | K/SECAM | |
| Czech Republic | | D/SECAM | K/SECAM | |
| Romania** | | D/PAL | G/PAL | |

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| Country/Geographical area | | System used in bands: | | | |
|---|---|---|---|---|---|
| | | I/III VHF broadcasting (Band 8) | | IV/V UHF broadcasting (Band 9) | |
| United Kingdom of Great Britain and Northern Ireland | | – | (10) | I/PAL | (4) |
| Russian Federation | | D/SECAM | | K/SECAM | |
| Rwandese Republic | (1) | B/PAL | | K1/SECAM* | (1) |
| San Marino (Republic of) | | | | | |
| Saint Vincent and the Grenadines | | | | | |
| Solomon Islands | | | | | |
| Western Samoa (Independent State of) | | | | | |
| St. Christopher and Nevis | | M/NTSC | | – | |
| Sao Tome and Principe (Democratic Republic of) | (1) | B/PAL | | – | (1) |
| Senegal (Republic of) | (1) | K1/SECAM | | K1/SECAM* | (1) |
| Seychelles | (1) | B/PAL | | – | (1) |
| Sierra Leone | (1) | B/PAL | | G/PAL* | (1) |
| Singapore (Republic of) | | B/PAL | | G*/PAL | (11) |
| Slovenia (Republic of)** | | B/PAL | | G/PAL | |
| Somali Democratic Republic | (1) | B/PAL | | G/PAL* | (1) |
| Sudan (Republic of the) | (1) | B/PAL | | G/PAL* | (1) |
| Sri Lanka (Democratic Socialist Republic of) | | B/PAL | | G/PAL | |
| South Africa (Republic of) | | I/PAL | | I/PAL | |
| Sweden | (4) | B/PAL | | G/PAL | (4) |
| Switzerland (Confederation of)** | | B/PAL | | G/PAL | (12) |
| Suriname (Republic of) | | M/NTSC | | – | |
| Swaziland (Kingdom of) | | | | | |
| Tanzania (United Republic of) | (1) | I/PAL | | I/PAL | (1) |
| Chad (Republic of) | (1) | K1/SECAM* | | K1/SECAM* | (1) |
| Thailand | | B/PAL | | G/PAL* | |
| Togolese Republic | (1) | K1/SECAM | | K1/SECAM* | (1) |
| Tonga (Kingdom of) | | | | | |
| Trinidad and Tobago | | | | | |
| Tunisia | (13) | B/SECAM, PAL | | G/SECAM, PAL | (13) |
| Turkmenistan | | | | | |
| Turkey** | | B/PAL | | G/PAL | |

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| Country/Geographical area | System used in bands: I/III VHF broadcasting (Band 8) | System used in bands: IV/V UHF broadcasting (Band 9) |
|---|---|---|
| Ukraine | D/SECAM | K/SECAM |
| Uruguay (Eastern Republic of) | N/PAL | – |
| Vanuatu (Republic of)** | B/PAL | – |
| Venezuela (Republic of) | M/NTSC | M/NTSC |
| British Virgin Islands | M/NTSC | – |
| Viet Nam (Socialist Republic of) | D/SECAM | K/SECAM |
| Yemen (Republic of) (1) | B/PAL | G/PAL* (1) |
| Yugoslavia (Federal Republic of) | B/PAL | G/PAL |
| Zaire (Republic of) (1) | K1/SECAM | K1/SECAM* (1) |
| Zambia (Republic of)** (1) | G/PAL* | G/PAL* (1) |
| Zimbabwe (Republic of) (1) | G/PAL* | G/PAL* (1) |

(1) This information has been taken from the preliminary requirements file as submitted by the Administrations concerned to the ITU in preparation of the Second Session of the Regional Administrative Conference for the planning of VHF/UHF television broadcasting in the African Broadcasting Area and Neighbouring Countries (AFBC(2)). In a number of cases transmitters using different systems from those indicated in the requirements file may continue to operate for a transitional period.

(2) The Federal Republic of Germany, Austria, Italy and the Netherlands use an additional FM carrier for stereophonic or two-channel sound transmission.

(3) Australia uses nominal modulation levels as specified for System I. For stereophonic sound transmission, an additional FM carrier is used similar to the system used in the Federal Republic of Germany.

(4) Denmark, Spain, Finland, Iceland, Norway, New Zealand, the United Kingdom and Sweden have approved the use of an additional digital carrier for stereophonic or multi-channel sound transmission.

(5) In the French Overseas departments and territories, the system K1 is used instead of L/SECAM which is used in the metropolitan area.

(6) In France, the use of an additional digital carrier for stereophonic or multi-channel sound transmission is being investigated.

(7) System I will be used at all stations though with a vision-to-sound ratio of up to 10/1. In addition Ireland reserves the right to the possible use of an additional sound carrier in the band between 5.5 MHz and 6.75 MHz in relation to the vision carrier.

(8) No final decision has been taken about the width of the residual sideband, but for planning purposes this country is willing to accept the assumption of a residual sideband 1.25 MHz wide.

(9) In New Zealand the modulation levels are identical to those of System I.

(10) The United Kingdom has ceased to use Bands I and III for television broadcasting.

(11) Singapore reserves the right to use additional frequency-modulated sound channels in the band between 5.5 and 6.5 MHz in relation to the picture carrier, for additional sound channels for sound broadcasting.

(12) The Swiss Administration is planning to use additional frequency-modulated sound carriers, in the frequency interval between the spacings of 5.5 and 6.5 MHz in relation to the picture carrier, at levels lower than or equal to the normal level of the sound carrier, for additional sound-tracks or for sound broadcasting.

(13) In Tunisia SECAM is used for broadcasting the national programmes; PAL is used for rebroadcasting other programmes.

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APPENDIX 2

TO ANNEX 1

**Chief technical characteristics of the SECAM IV colour television system**

## 1 Signals transmitted

SECAM IV is compatible with standard black-and-white 625-line television systems, except system N. The luminance signal is obtained from gamma-corrected primary signals $E'_R$, $E'_G$, $E'_B$, and corresponds to the equation:

$$E'_Y = 0.30\,E'_R + 0.59\,E'_G + 0.11\,E'_B$$

The colour information is transmitted by two colour-difference signals:

$$D'_R = \frac{1}{1.14}\,(E'_R - E'_Y)$$

$$D'_B = \frac{1}{2.03}\,(E'_B - E'_Y)$$

Before modulation, the frequency band of the colour-difference signals occupies more than 1.5 MHz.

## 2 Transmission procedure

The colour-difference signals are transmitted by modulation of a sub-carrier. They are differentiated from one line to the next as follows:

*Signal transmitted during one of the lines*

$$E_{S1} = \left\{\sqrt{D'^2_B + D'^2_R} + E_p\right\} \cos\left[\omega_0\,t + \varphi(t)\right]$$

*Signal transmitted during the following line*

$$E_{S2} = \left\{\sqrt{D'^2_R + D'^2_B} + E_p\right\} \cos\left(\omega_0\,t + \varphi_0\right)$$

where:

$E_p$ is a d.c. voltage equal to 10% of the maximum signal,

$$\varphi(t) = \arctan\,(D'_B \,/\, D'_R)$$

## 3 Frequency of the colour sub-carrier

The frequency of the colour sub-carrier is equal to: $f_0$ = 4.43361875 MHz. It is related to the line sweep frequency, $f_H$ = 15 625 Hz, by the following equation:

$$f_0 = (284 - 1/4)\,f_H + 25\text{ Hz}$$

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## 4 Colour synchronization signal

The receiver switch is synchronized by synchronization signals transmitted with the composite video signal. They represent six wave trains of the colour sub-carrier, each train lasting about 40 µs. They are transmitted during the field returns in the 6th-11th lines of the first field and in the 319th-324th lines of the second field. During the even lines, the sub-carrier phase in the train is $\varphi = 90°$, and during all the odd lines $\varphi = 180°$. The amplitude of each wave train is equal to 30% of the composite signal $E'_Y$ measured between the white and black levels.

## 5 Reception procedure

The colour-difference signals $D'_R$ and $D'_B$ are obtained by multiplication of the transmitted signals $E_{(2n+1)}$ and $E_{2n}$, each signal being delayed in turn by the duration of one line. The level of the signal $E_{2n}$ must be 10 to 20 times higher than that of the signal $E_{(2n+1)}$.

To obtain the correct polarity for the signals $E'_{R-Y}$ and $E'_{B-Y}$, at each line, a switch working to the line periodicity is used.

ANNEX 2

## Colorimetric standards in colour television

1 In 1953, when the NTSC colour television system was adopted for transmission in the United States of America, the colorimetry of the system was based on three specific primary colours and a reference white. The coordinates of the primaries were (the coordinates are given in the CIE system (1931)):

| | | |
|---|---|---|
| Red: | $x = 0.67$ | $y = 0.33$ |
| Green: | $x = 0.21$ | $y = 0.71$ |
| Blue: | $x = 0.14$ | $y = 0.08$. |

The reference white chosen was standard:

White C: $x = 0.310$ $y = 0.316$.

2 When the PAL and SECAM systems were first designed, they were based upon the colorimetric standards of NTSC. As a result, the coefficients used for determining the signals involved in coding PAL and SECAM (the luminance signal and the colour-difference signals) were directly based upon the chromaticities given in § 1.

3 However, it has been recognized that there have been continuing changes in the chromaticities of the phosphors used in making colour picture tubes over the years, and that those actually used do not have the same primary chromaticities as those which served to establish the coding of systems. Nevertheless, in all systems the coefficients used for determining the signals involved in coding (the luminance signal and the colour-difference signals) are directly based upon the chromaticities and white point given in § 1.

4 Several solutions have been proposed or implemented, in different countries, for compensating or correcting the effect upon colour reproduction of this difference between the receiver characteristics and the standards given in § 1.

5 The United States of America continues to base the colorimetry of its transmissions upon NTSC primaries whose chromaticities and white point are defined in § 1. Studio monitors are adjusted to a reference white of $D_{65}$. However, because picture tubes do not yet contain phosphors whose chromaticities are the same (or very nearly the same) as those defined in § 1, approximate corrections, involving operations upon the electrical signals, are made in receivers in order to achieve satisfactory colour reproduction. Further, to achieve greater consistency in colour transmissions, the United States of America recommends that the picture monitors used in studios should also contain correction circuits which cause the colour reproduction to approximate to that which would have been obtained if the picture tubes used in the monitors had contained phosphors with the primary chromaticities shown in § 1.

6 In Japan, the colorimetry of the system is based upon the primary chromaticities and white point given in § 1. Studio monitors are adjusted to a white point of $D$, 9300 K.

7 In the 625-line PAL and SECAM systems, the colorimetry is now based upon the three specific primary colours (see Note 1):

| | | |
|---|---|---|
| Red: | $x = 0.64$ | $y = 0.33$ |
| Green: | $x = 0.29$ | $y = 0.60$ |
| Blue: | $x = 0.15$ | $y = 0.06$ |

and reference white $D_{65}$.

These chromaticities are closely representative of the phosphors incorporated in the picture tubes of many of the receivers and studio monitors used in those countries that have adopted the 625-line PAL and SECAM systems. Thus, in such receivers and monitors, no electrical corrections are required in order to achieve good colour reproduction. Further, in order to improve the consistency of colour reproduction, when the television receiver is switched from one programme to another, it has been suggested that the chromaticities of the phosphors used in studio monitors should be standardized. The assessment is based upon a method of tolerance which takes account of both the primary chromaticities of the tube phosphors and the effect of their combined chromaticities upon the reproduction of a typical skin tone.

NOTE 1 – These coordinates are given in the CIE system (1931). For 625-line SECAM systems, it is provisionally permitted (for existing equipment), to use the chromaticity coordinates and reference white given in § 1.

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